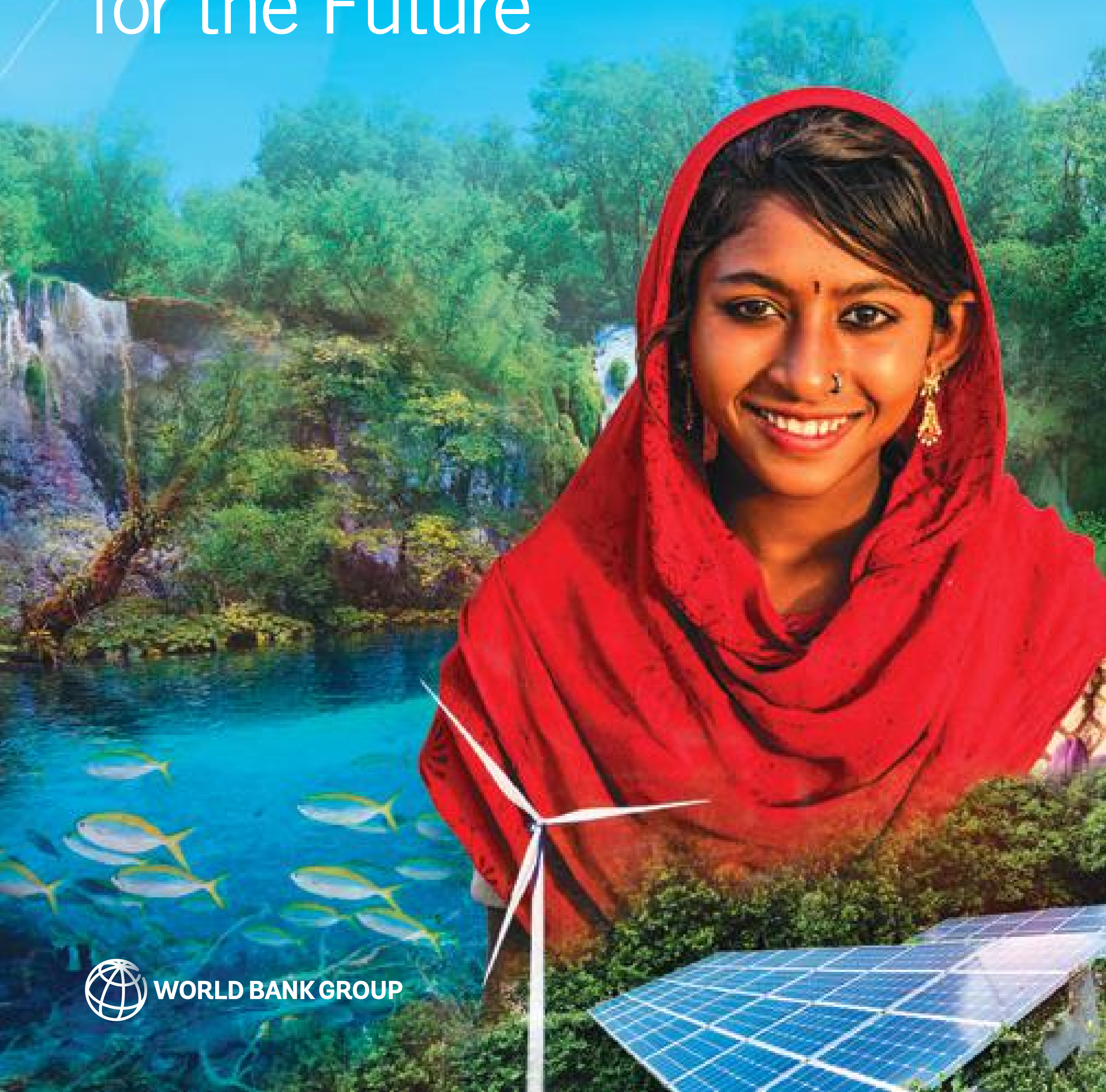
The Changing Wealth of Nations 2021

Managing Assets for the Future



WORLD BANK GROUP

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Foreword

More than a decade ago, the World Bank launched a groundbreaking publication titled *Where Is the Wealth of Nations?*, the first in a series introducing the concept of wealth as a complementary indicator to gross domestic product (GDP) for monitoring sustainable development in a country. For the first time, we showed that development is about managing a broad portfolio of assets—including natural, human, and produced capital. Just as a company measures its value by looking at both its income statement and balance sheet, a look at comprehensive national wealth signals whether GDP growth can be sustained over the long run.

Since we launched this series, the challenges facing the world have become more urgent and more severe: from the rising impacts of climate change and the need for global action on the low-carbon transition, to the loss of biodiversity and ecosystem services, to governments grappling with the COVID-19 (Coronavirus) pandemic and ensuing economic crisis. There is now strong recognition of the need for collective action to address these global issues. *The Changing Wealth of Nations 2021*, which covers 146 countries over more than 20 years (from 1995 to 2018), provides data and analysis to help meet this challenge.

There is some good news in this latest edition: global wealth (as measured by natural, human, and produced capital) grew significantly between 1995 and 2018, and middle-income countries are catching up to high-income countries, mainly due to rapid growth in Asia. Upper-middle-income countries saw their total wealth more than double during this period.

However, the wealth accounts also indicate areas of concern. Unfortunately, inequality between countries persists. Between 1995 and 2018, low-income countries' share of global wealth hardly changed, remaining below 1 percent despite being home to about 8 percent of the world's population. Furthermore, countries with a disproportionate share of wealth in individual assets, particularly subsoil resources such as oil, gas, and minerals, have faced volatile and even declining wealth.

What really matters is wealth per capita, and here the changes are even more troubling. In 26 countries, wealth per capita stagnated or declined between 1995 and 2018, and almost half of these were in Sub-Saharan Africa. If the trend continues, future generations will be materially worse off. In other words, the development path is unsustainable. Renewable natural capital forms a very large share of wealth for low-income countries—it is of great development importance to manage this wealth carefully and not deplete natural assets for a short-term income boost.

We hope that the data in this report will be used by policy makers to improve measures of economic progress and help drive policies that improve lives. By better managing, measuring, and valuing natural assets, we can give our environment the ability to enhance our well-being. By recognizing the importance of human capital, we can move beyond a focus on short-term profits to one based on investments in skills and a healthy population.

Governments are key, but they are not the only actors. Individuals, companies, and investors are all managers of assets, and the choices they take can make a difference, too. Comprehensive wealth accounts have the potential to improve environmental, social, and governance (ESG) measures by providing insights into the changing natural wealth in monetary value terms at the country level.

With a better understanding of global wealth, we can all work toward development that is greener, more inclusive, and more resilient.

Mari Elka Pangestu
Managing Director, Development Policy and Partnerships
The World Bank

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Chapter authors include Matthew Agarwala, Yewande Awe, Michael W. Beck, Maksym Chepeliev, Shun Chonabayashi, James Cust, Alexander Golub, Ekaterina Gratcheva, Nada Hamadeh, Diego Herrera, Andrei Ilas, Javier Gustavo Inon, Kenan Karakulah, Vicky W. Y. Lam, Glenn-Marie Lange, Pierre Mandon, Pelayo Menéndez, Esther Naikal, Grzegorz Peszko, Marko Rissanen, Alexis Rivera Ballesteros, Robert Smith, U. Rashid Sumaila, Dominique van der Mensbrugghe, Dieter Wang, and Dimitri Zenghelis.

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About the Editors and Authors

Editors

James Cust is a Senior Economist in the Office of the Chief Economist, Africa Region, and leads *The Changing Wealth of Nations* program at the World Bank. He also co-convenes the Chief Economists of Government initiative, a peer network of chief economic advisers to 40 African presidents. They meet regularly to discuss pressing policy questions. Before this, he was Director of Research and Data at the Natural Resource Governance Institute and helped create the Natural Resource Charter. Jim's research addresses policy-relevant empirical questions on the role of government in harnessing resources for prosperity. He recently completed work on institutions and locations of oil exploration; on stranded nations, examining the intersection of climate policy and resource wealth; and on the "presource curse," tracing the macroeconomic challenges posed by major oil discoveries that precede the traditional resource curse problems. He is an external Research Associate of the Oxford Centre for the Analysis of Resource-Rich Economies at the Department of Economics, University of Oxford. Jim holds a DPhil (PhD) in economics from the University of Oxford.

Diego Herrera is an Environmental Economist at the World Bank's Environment, Natural Resources, and Blue Economy Global Practice. Diego's research addresses the interactions between forest conservation and development policies. At the World Bank he is supporting global and country-level efforts to value natural capital and manage wealth accounting global databases. Before joining the World Bank, Diego was an Economist at the Environmental Defense Fund, where he helped design economic and financial instruments for the protection of tropical forests and coastal ecosystems, and a Postdoctoral Associate at the Gund Institute for Environment, University of Vermont, where he modeled the human health impacts of forest and watershed conservation in low- and middle-income countries. Diego holds a PhD in environmental economics and policy from Duke University. His doctoral thesis assessed the impacts of Brazilian Amazon protected areas on deforestation, roads, and human migrations.

Glenn-Marie Lange has worked for more than 30 years to develop innovative approaches to managing the interdependence of natural resources, development, and poverty reduction. As a Senior Economist at the World Bank over the past 12 years, she established and led the World Bank's global program, Wealth Accounting and the Valuation of Ecosystem Services (WAVES), across 20 countries and she led the innovative flagship series, *The Changing Wealth of Nations*. She helped build the World Bank's new program on the Blue Economy, with a focus on seascape management and bringing economic valuation into marine spatial planning, as well as a new World Bank initiative on nature-based solutions, including work on mangroves and coral reefs in countries including Jamaica and the Philippines. Before joining the World Bank, Dr. Lange was a Senior Researcher at the Earth Institute at Columbia University (2004–08) and at New York University's Institute for Economic Analysis (1990–2004) and has been a Pew Fellow in marine conservation since 2006. During this time, she pioneered the use of ecosystem services valuation and natural capital accounting to integrate environmental concerns into macroeconomic and sectoral policy analysis. She has worked extensively in East and Southern Africa, as well as in several Asian and Latin American countries over the past 20 years. She received a PhD in economics from New York University in 1990.

Esther Naikal is an Economist in the World Bank's Climate Change Group. In her previous role as Economist in the Environment, Natural Resources, and Blue Economy Global Practice, she managed the natural capital and wealth accounting global databases and valuation methodology, leading the production and updating of the adjusted net saving indicators published annually in the World Bank's World Development Indicators and the comprehensive wealth accounts published in *The Changing Wealth of Nations* report series. Esther has conducted analytical work and coauthored technical papers on wide-ranging topics, including valuing wealth using purchasing power parities, improving the estimates of mineral resource rents, extending total factor productivity to include natural resources, and analyzing the Russian Federation's national wealth. Esther has a master's degree in economics from the University of Maryland.

Grzegorz Peszko is a Lead Economist in the Global Platforms Team of the Environment, Natural Resources, and Blue Economy Global Practice of the World Bank, where he leads analytical and advisory services on the economics of climate change mitigation—especially in fossil fuel–rich countries, pollution, the circular economy, green jobs, and macrofiscal aspects of sustainability. He has more than 30 years of academic, policy, and project experience in economic, energy, environmental, and natural resources management issues. Before joining the World Bank, Grzegorz was a Lead Economist at the European Bank for Reconstruction and Development, Program Manager at the Organisation for Economic Co-operation and Development, Professor at the Krakow University of Economics, and the Head of the Economic Unit in the Department for EU Integration in the Polish Ministry of Environment. He served as board member of the Krakow Environmental Investment Fund and worked as a consultant for various private and public clients, a radio and TV journalist, and a tram driver. He was the lead author of the *Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report* and is a contributing author of the forthcoming *IPCC Sixth Assessment Report*. Grzegorz holds a PhD in economics from the Krakow University of Economics, an MSc in environmental economics from University College London, and an MSc in political science and journalism from Jagiellonian University.

Authors

Matthew Agarwala, Project Leader, Wealth Economy Project, Bennet Institute for Public Policy, University of Cambridge

Yewande Awe, Senior Environmental Engineer, World Bank

Michael W. Beck, Research Professor, University of California Santa Cruz

Maksym Chepeliev, Research Economist, Center for Global Trade Analysis, Purdue University

Shun Chonabayashi, Economist, World Bank

Alexander Golub, Adjunct Professor, American University

Ekaterina Gratcheva, Lead Finance Officer, World Bank

Nada Hamadeh, Program Manager, World Bank

Andrei Ilas, Analyst, RES Kapital Partners

Javier Gustavo Inon, Consultant, World Bank

Kenan Karakulah, Consultant, World Bank

Vicky W. Y. Lam, Fisheries Economist and Program Manager, Nereus Program, University of British Columbia

Pierre Mandon, Consultant, World Bank

Pelayo Menéndez, Postdoctoral Research Fellow, University of California Santa Cruz

Marko Rissanen, Senior Statistician, World Bank

Alexis Rivera Ballesteros, Consultant, World Bank

Robert Smith, Principal, Midsummer Analytics

U. Rashid Sumaila, Professor, Institute for the Oceans and Fisheries and School of Public Policy and Global Affairs, University of British Columbia

Dominique van der Mensbrugghe, Research Professor and Director, Center for Global Trade Analysis, Purdue University

Dieter Wang, Consultant, World Bank

Dimitri Zenghelis, Special Adviser, Wealth Economy Project, Bennet Institute for Public Policy, University of Cambridge

Summary for Policy Makers

Introduction

The COVID-19 pandemic and the increasingly severe impacts of climate change provide stark reminders of how vulnerable human prosperity can be to forces outside of economies. They highlight how our relationship to the natural environment can exacerbate the many other risks we face. Mismanagement of nature and failure to consider the longer-term impacts of our actions can carry severe consequences, even if they might not be immediately evident. We therefore need an expanded economic toolkit, including broader measures of economic progress, to secure our collective prosperity and even sustain our existence as a species.

Wealth accounting—the balance sheet for a country—captures the value of all the assets that generate income and support human well-being. Gross domestic product (GDP) indicates how much monetary income or output a country creates in a year; wealth indicates the value of the underlying national assets and therefore the prospects for maintaining and increasing that income over the long term. GDP and wealth are complementary indicators for measuring economic performance and provide a fuller picture when evaluated together. By monitoring trends in wealth, it is possible to see whether GDP growth is achieved by building capital assets, which is sustainable in the long run, or by liquidating assets, which is not. Wealth should be used alongside GDP to provide a means of monitoring the sustainability of economic development.

The Changing Wealth of Nations 2021 (CWON 2021) finds that our material well-being is under threat: from unsustainable exploitation of nature, from mismanagement and mispricing of the assets that make up national wealth, and from a lack of collective action at local, national, and regional levels. CWON 2021 provides the data and analysis that can promote a more sustainable approach to prosperity and help policy makers navigate these challenges. The report draws on a unique global asset database that allows detailed examination of the underlying value of a nation's wealth, taking into account human, produced, and natural capital and noting where assets are being managed sustainably or unsustainably. CWON 2021 presents the world's most comprehensive accounts to date of the wealth of nations that comprise not only what was made by people (produced capital) but also the wealth embedded in people themselves (human capital), and the wealth offered by nature (natural capital).

This report does not simply examine the historical wealth of nations; it provides the cutting-edge tools to manage wealth for the future. How do our collective actions impact the value of our natural and human assets? How will climate change affect the value of fossil fuel resources, and how should governments respond? How can policy better account for the value of ecosystem services such as the protection provided by mangroves or the value to people of protected natural areas? Robust answers to such questions have been elusive, and CWON 2021 provides them. The analysis in this report and the accompanying database will help policy makers weigh national, regional, and global risks, and in the face of those risks determine how to build wealth that is sustainable over generations.

CWON 2021 marks a significant advance in how to measure and assess the sustainability of economic development. The report includes 146 countries and every year back to 1995, and it does so in a way that is both rigorous and comparable across space and time. This analysis does not claim to reflect all the intrinsic values of human or natural capital, but instead provides measures that are compatible with systems of national accounting. By doing so, CWON 2021 demonstrates that natural and human forms of capital deserve consideration at the highest levels of government and are also worthy investments to promote sustainable prosperity.

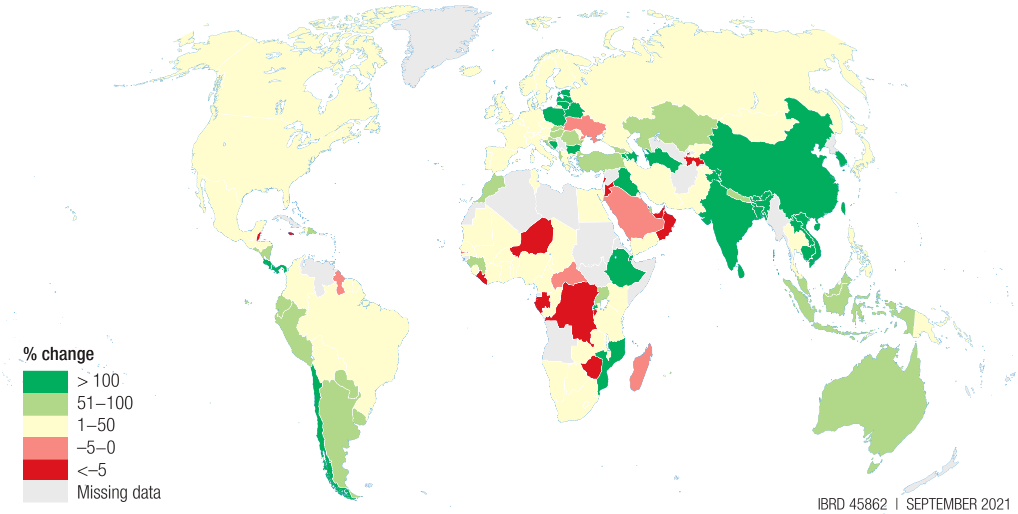
Global Wealth Has Never Been Greater, but the Risks Faced Have Also Never Been Greater

In many countries, GDP is increasing at the expense of total wealth and future prosperity. If not properly informed, citizens might mistakenly expect their improving prosperity to continue indefinitely. However, if rising GDP today comes at the expense of declining *wealth per capita*, then prosperity will be unsustainable. Economic growth will erode its own base.

CWON 2021's measure of the change in wealth per capita over time is perhaps the most important metric to consider in addition to GDP, and it provides an actionable way to track sustainability. Despite a global expansion in total wealth per capita between 1995 and 2018 (map PS.1), many countries are on an unsustainable development path because their natural, human, or produced capital is being run down in favor of short-term boosts in income or consumption. In countries where today's GDP is achieved by consuming or degrading assets over time, for example by overfishing or soil degradation, total wealth is declining. This can happen even as GDP rises, but it undermines future prosperity.

Measuring the change in wealth per capita, and contributions from individual wealth components, allows policy makers to monitor the sustainability of development and its resilience to shocks. Countries can

MAP PS.1 Growth of Total Wealth per Capita, 1995–2018



Source: World Bank.

identify asset management policies that make future prosperity more sustainable, resilient, and equitable. CWON 2021 finds that while total wealth has increased everywhere, albeit with a widening gap between nations, per capita wealth has not. More than a third of low-income countries saw falling wealth when measured in per capita terms as wealth creation failed to keep pace with population. Declining wealth per capita breaks a core principle of sustainability: future generations should be left no worse off than current generations.

Global wealth inequality is also increasing. Low-income countries are falling further behind in terms of their share of global wealth. If they are to catch up with the rest of humankind, they will need their overall wealth, including human, natural, and produced assets, to grow at an above-average rate. This edition of CWON finds that precisely the opposite is occurring. Low-income countries are expanding their wealth at a relatively slow rate, as reflected in the global shares of wealth: between 1995 and 2018, the share of low-income countries in global wealth hardly changed, remaining below 1 percent despite being home to about 8 percent of the world's population.

CWON 2021 Recommends Four Priorities for Policy Action

1. *Measure and monitor wealth to boost sustainability and prosperity.* Governments should measure and monitor wealth, alongside GDP. They can use the System of National Accounts (SNA) framework and the System of Environmental-Economic Accounting (SEEA) standards to integrate wealth accounting systematically into national balance

sheets. CWON provides the world's most comprehensive and SNA-compatible international data on wealth that can be used as a benchmark and proxy in the absence of detailed bottom-up national wealth accounts. Other actors such as financial markets can utilize wealth accounting to track sustainability and environmental, social, and governance (ESG)–related indicators.

2. *Invest in sustainable wealth*. Governments should create enabling conditions for balanced investments in all components of wealth, not just produced and nonrenewable assets but also human and renewable natural capital. Assets representing common and public goods, like education and public health and often the wealth provided by nature, will require public investments or active government intervention to establish property and use rights to prevent depletion or unsustainable conversion to other forms of capital. Governments also have the duty to correct market failures to enable private investment in wealth creation by aligning private returns to investments with the public benefits and damages they create.
3. *Create policy incentives to protect and increase the value of wealth*. Where government policies are designed to maximize short-term income only, results can come at the expense of future income and well-being opportunities. Wealth accounting helps identify and correct such policy failures. Assets that are mispriced get mismanaged. Environmentally harmful produced capital and fossil fuels are often overrewarded by markets, while essential human and renewable natural assets are often undervalued and underpriced. This leads to the latter's degradation and depletion, with systemic risks to macrofiscal stability and potentially existential risk to humans. Governments should therefore use policies and pricing to support socially beneficial assets and do the reverse for those with negative external effects.
4. *Diversify and rebalance the asset portfolio to make growth resilient to external shocks.* Multiple environmental crises (climate change, biodiversity loss, ocean damage, and pollution) increase the intensity and frequency of external shocks to growth while also making these shocks more difficult to predict. Standard economic recipes for product and export diversification beyond commodities are no longer sufficient, as they often lead to accumulation of produced assets in emission-intensive manufacturing and land use. Diversification of *wealth*—the assets that countries rely on to generate income—can instead make economic development more resilient to uncertain external factors such as climate change and global decarbonization. A diverse asset portfolio is also more sustainable than one overly dependent on single assets, particularly depleting ones such as oil, gas, and some minerals.

These policy recommendations are informed by expanded wealth accounts, and accompanying analysis contained in the new CWON 2021 report. More detailed policy discussion can be found in the report and in the policy matrix presented in table PS.1 at the end of this summary.[1]

Policy Priority 1: Measure and Monitor Wealth to Boost Sustainability and Prosperity

CWON's balance sheet approach to asset valuation, rigorously based on both the SNA framework and the SEEA, provides comparable and comprehensive measures of wealth. This allows ministries of finance and national treasuries to consider monetary trade-offs and the important role for asset accumulation across natural capital, human capital, and produced capital. It also shines a light on the role of capital degradation, depletion, and depreciation, which can undermine the sustainability of economic growth. For some assets, particularly natural assets, this monetary valuation can help ensure they get an appropriate level of economic policy consideration, given their importance to sustainable economic prosperity.

Because low-income countries have so few other assets, proportionately, renewable natural assets such as land and ecosystems are crucial for them, comprising around 23 percent of their total wealth. This is the highest fraction of total wealth coming from renewable natural capital among all income groups. Nonetheless, it is still likely to be a conservative estimate as several ecosystem services—most notably, natural carbon storage—cannot yet be included pending updates to SEEA methodologies. As a consequence, governments may be tempted to seek a short-term boost to consumption and growth by liquidating them. However, higher income levels are associated with success in enhancing the value of natural capital, not degrading it.

Sustainable well-being depends on well-functioning ecosystems and educated populations. Natural and human capital are therefore at the core of our prosperity, but few of these assets are accounted for in the national balance sheets and hence appear invisible or worthless to policy makers. When we think of wealth, most of us might think about financial assets, or companies, computers, and cars. But what about forests, mangroves, water, fish, or clean air? What about healthy people and their capacity for productive work? And can we cooperate when the challenges in managing our prosperity transcend national boundaries? Properly accounting for wealth can help us better manage it, work cooperatively across borders, and ensure that our prosperity is sustainable. CWON 2021 provides the data and analysis that can help.

Policy Priority 2: Invest in Sustainable Wealth

The wealth of nations is inextricably linked to the policy choices nations make—it is not static and independent of government. Policy choices change the trajectories and composition of that wealth; price assets incorrectly, and economies may become exposed to needless risks and dependencies.

Where wealth per capita is declining, there is insufficient investment in a nation's assets, or they are being mismanaged or misvalued. Actions to enhance the value of human capital, for example, would include the creation of quality jobs, fair salaries, and investments to improve the education and health of citizens. Investments in produced capital would include the construction and maintenance of public infrastructure, buildings, and cities that enable citizens to lead productive lives. For natural capital, wealth can be built through nature restoration or improving the fertility of agricultural land, but it can also encompass protection of sensitive ecosystems such as forests to enhance their value.

Human capital, measured by the value of earnings over a person's lifetime, is the most important component of wealth globally. It constituted a staggering 64 percent of global wealth in 2018. CWON 2021 provides wealth accounts for human capital disaggregated by gender and employment status. By measuring human capital in terms of expected lifetime earnings, CWON 2021 provides policy makers with a direct view into the value people can obtain in the labor market. Job creation and quality jobs will be a critical challenge of the twenty-first century, particularly in countries with young and fast-growing populations. CWON 2021 measures can help policy makers evaluate past successes and future opportunities to boost human capital—and the economic opportunities for people—as part of the development process.

High levels of air pollution and other drivers of environmental health are harming people and limiting the world's human capital. Such factors can be integrated into human capital valuations, as premature deaths and disabilities reduce expected earnings. Pollution of outdoor and indoor air is one of the world's leading environmental risk factors to health, accounting for over 6 million premature deaths in 2019.

The consequences of COVID-19 have already had a negative impact on people's lives and livelihoods around the world. The resulting economic downturn and associated unemployment and loss of earnings have already set back the long-term trajectory of poverty reduction, especially in low-income countries. This can be quantified in terms of the impact on human capital in the wealth of nations.

Policy Priority 3: Create Policy Incentives to Protect and Increase the Value of Wealth

Governments have a role to play by enacting regulatory and fiscal incentives to better reflect the societal costs and benefits provided by different asset classes in their market prices. This can improve the efficiency and sustainability of natural capital utilization, such as protecting fisheries from overexploitation, taxing carbon emissions to signal to the market the full societal value of assets, or paying for ecosystem services. This can build national wealth and help to address global challenges such as climate change.

CWON 2021 finds the countries falling behind the most are often those struggling to manage their assets in sustainable ways. Declining stocks of renewable natural capital, for example, may reflect overexploitation or degradation of ecosystem services, and many of the 26 countries with declining or stagnant wealth per capita are those with falling values of natural capital per capita. New CWON 2021 decomposition analysis, which breaks down wealth changes into quantity and unit value components, can help shed light on what may be driving these patterns and how policy makers might respond.

Countries that mismanage nature are also more vulnerable to economic shocks. Failing to diversify a nation's assets puts growth at risk. Many countries with abundant mineral and fossil fuel resources have struggled to use the income from these assets to diversify the wealth base of their economies. CWON 2021 finds that when an external shock—such as a fall in commodity prices—hits, their entire economy is vulnerable and total wealth per capita can decline. Meanwhile, countries that have diversified their wealth are better equipped to weather such storms.

Without better regulations and changing social norms regarding how we value nonfinancial assets, many categories of wealth, including natural and human capital, will remain mispriced and hence mismanaged. Low-income countries will not catch up, and global wealth will be put at even greater risk.

Wealth held in renewable natural capital per person is greater in high-income than in low-income countries. This is encouraging news. It suggests that far from there being a trade-off between economic development and nature, they can be complements: prosperous countries are those that have protected and enhanced their natural assets, such as forests, fisheries, landscapes, productive land, and the value and scale of protected areas. Improving economic productivity of nature and of people is a key driver underpinning this trend. Therefore, low-income countries can emulate this strategy and prioritize both nature and overall economic prosperity at the same time.

The CWON accounts provide new ways to measure sustainability in the context of material well-being. However, changes in wealth per capita provide only a measure of "weak" sustainability that implicitly assumes a high degree of substitutability among different asset classes. The emergence of multiple global crises, such as biodiversity loss, climate change, and ocean pollution, is a strong wake-up call about the limits to replacing critical ecosystem services with human-made substitutes.

Policy Priority 4: Diversify and Rebalance the Asset Portfolio

Overdependence on any single asset category in national wealth, particularly commodities, is risky for countries. Nonrenewable natural capital assets (for example, comprising fossil fuel and mineral wealth) grew rapidly from 1995 until around 2014, but they have been declining in value since then, driven mainly by falling petroleum prices. Countries reliant on such resources for exports and government revenues were hit hard by this decline. Many of the 26 countries with declining or stagnant wealth per capita in this period were resource-rich, commodity-dependent countries. This edition of CWON provides new analysis on asset diversification and concentration to help policy makers achieve greater economic diversification to help manage and reduce these risks in the future.

What about the impact of climate change policies on fossil fuel wealth? CWON finds that as the world moves toward low-carbon sources of energy, the value of oil, gas, and coal could decline by 13 to 18 percent by 2050. But what matters most is that this risk falls unevenly around the world. Some countries more reliant on fossil fuels are facing significant economic risk. They can manage this risk by adopting proactive policies to navigate their own transition away from a dependence on fossil fuel wealth. Traditionally, diversification meant moving beyond extractive industries to exporting processed fuel and fossil fuel–intensive products instead. Going forward, such approaches will be much riskier amid global efforts to decarbonize economic activities. Countries are now beginning to tighten their climate policies and restrict access to their markets for imported carbon-intensive products. International cooperation can also help manage such risks. But CWON 2021 finds that some fuel exporters may have weak economic incentives to cooperate without bold policy actions by fuel importers, such as border carbon adjustment taxes (BCATs), already proposed by the European Union.

Renewable energy endowments, such as water, wind, and sunlight, represent a potentially large but unaccounted-for wealth of nations. Renewable energy should be included in national balance sheets in a similar way to fossil fuel reserves. CWON 2021 presents an approach to doing so and finds that hydropower dominates renewable energy wealth, and its value exceeds the value of fossil fuels in some nonrenewable resource–rich countries. Better energy and climate policies can quickly unlock significant value from solar and wind energy assets. New analysis shows how policies can be used to increase the value of renewable energy to match the value of fossil fuel assets.

Using Wealth Accounting to Guide Policy

CWON 2021 contains not just updated and extended wealth accounts but also extensive policy analysis demonstrating how wealth accounts can help to guide policy choices. For example, CWON 2021 applies the lens of wealth to analysis of asset portfolio management under risk and uncertainty from factors such as climate change and global decarbonization. CWON 2021 does not attempt to predict the impact of rare and unexpected events that have potentially extreme or wide-ranging impacts and which may be more frequent with expected environmental crises, such as climate change and biodiversity loss, and which may include surprises such as the COVID-19 pandemic. Instead, CWON 2021 helps us understand and navigate uncertainty by providing scenarios that explore future wealth under several possible scenarios of climate change and climate policies. For human capital, CWON 2021 explores the impact of the COVID-19 pandemic and air pollution, illustrating how management of natural assets and human assets can interact. For fossil fuels, the scenario analysis identifies policy pathways to manage the risks of stranded assets through cooperative and noncooperative low-carbon growth strategies and BCATs. CWON 2021 also explores how policy reforms can enhance wealth creation from natural capital such as fisheries and renewable energy.

Conventional measures of fiscal sustainability overlook important wealth considerations, such as the depletion and degradation of natural capital, and even the destruction of produced assets by natural disasters.

For example, the source of government revenues may be unsustainable if it comes from extraction of nonrenewable assets, such as fossil fuels, or if it comes from an asset that is being mismanaged, such as an overfished fisheries sector or properties vulnerable to floods or cyclones. New analysis on the challenges of Dutch disease and resource dependence illustrate how countries might mitigate these risks and plan for declining demand for fossil fuels. By introducing information on the assets underlying government revenue sources, the wealth accounts can help guide more sustainable fiscal policy.

Future Work and Unanswered Questions

Although the analysis considers the potential impacts of climate change on asset value, CWON does not yet include the value of carbon retention or sequestration services as part of wealth embedded in biological ecosystems (for example, forests, soils, and oceans). Nor does it subtract the social cost of carbon from fossil fuels. There are ample cross-country data available to measure physical carbon balances but no final agreement about how to account for the value of climate regulation services in the SEEA.

Future versions of CWON will also seek to capture how social capital and biodiversity influence the value of assets in the core wealth accounts. These advances are somewhat different in nature. Biodiversity and social capital are what Dasgupta (2021) refers to as enabling characteristics of assets, a quality that gives value to other assets, rather than assets as such. Social capital may not easily be made part of the core monetary accounts, but new techniques to measure social capital can provide essential, complementary indicators to changes in total wealth per capita. Currently, wealth accounts do not fully capture the impact on renewable natural capital where losses and degradation have brought ecosystems to the point of potentially irreversible thresholds, which may precipitate catastrophic events on a scale that escapes the conceptual apparatus of traditional economics.

Further, improvements in data, including those gathered via remote sensing methods, open possibilities for greater spatial and temporal measurement of wealth. For example, by breaking down the wealth accounts at subnational levels of analysis, policy makers can see how unequal the distribution of wealth and different assets is across the country, and how that has evolved over time. This may also provide data and analysis to guide local decision-making.

CWON 2021 describes some of the main findings emerging from the new, expanded wealth accounts—the most comprehensive and SNA-compatible wealth accounts available so far. The analysis and the abundance of data—which are available online—should provide a rich toolkit for policy makers. Excel tools and interactive data visualizations can be used to analyze trends within countries, across time, and between peers. Breaking down accounts by individual assets, and decomposing wealth by quantity and unit value, can further guide choices about building wealth for the future.

Sustainable Prosperity Requires Collective Action at Local, National, and Global Levels

A green, resilient, and inclusive recovery from the pandemic-induced economic crisis demands urgent changes in how local and national governments manage their human, natural, and produced capital. It also requires unprecedented levels of international action and cooperation, including action to address climate change, loss of biodiversity, and other global challenges. This means combining domestic policies with international agreements on taxing externalities such as carbon emissions or agreements over the sustainable management of transboundary assets such as fish or water.

Going forward, policy interventions—such as carbon taxes and payments for ecosystems services—are urgently needed to make market prices explicitly reflect the social cost of carbon dioxide emissions and the value of global climate regulation services provided by nature. By ignoring polluting and climate change impacts and costs to society, fossil fuel assets are overvalued in the market. Yet assets that can help in climate mitigation efforts, such as forest ecosystems, are undervalued.

Governments are not the only actors that matter. Individuals, companies, and investors are all managers of assets, and the choices they make can make an important difference. Financial markets, for example, have started to take sustainable development seriously as part of decision-making. This includes major progress on incorporating ESG considerations into investing choices. However, ESG often relies on environmental measures that can overweight physical properties (for example, hectares of forest cover) while underestimating the asset value and the long-term economic benefits of sustainable management of natural resources (for example, expressed via natural capital accounts in CWON). Wealth data have the potential to improve ESG measures by providing insights into the changing natural wealth in monetary value terms at the country level. This can be used, for example, to inform sovereign ESG scores.

By better managing, measuring, and valuing natural assets, we can give our natural environment the ability to grow and enhance our well-being. By recognizing the importance of human capital, we can move beyond a focus on short-term profits and incomes to one based on investments in skills and a healthy population that will ensure continuous prosperity. By considering wealth distribution, we can ensure more inclusive and resilient growth in material well-being. Economic development, flourishing humans, and nature can all be complements—indeed, they must be treated as complements if humans are to thrive on this planet.

TABLE PS.1 Policy Matrix and Guide to Further Details

Assets	Priority policy areas	Further details	Measure and track wealth	Policies to invest in wealth	Policies to increase value of wealth	Diversify assets to manage risks
Renewable natural capital	• Forests: Policies and investments to prevent deforestation and forest degradation can enhance overall natural capital wealth, especially in low-income and lower-middle-income countries, which, as a group, show a decline in forest timber and forest ecosystem services wealth per capita. Mechanisms that make visible the full value of forest ecosystem services can help incentivize protection and sustainable use, relative to timber and agricultural uses.	Chapter 5		✔	✔	
	• Critical services provided by forests and other ecosystems include retention (stock) and sequestration (flow) of carbon. Markets so far failed to reflect this value in widespread carbon prices. Domestic policy action to price carbon, alongside internationally comparable accounting standards consistent with SEEA, may pave the way for the emergence of global demand and willingness to pay for retention and sequestration services provided by ecosystems and stem overuse of forests for timber or clearance.	Chapter 1			✔	
	• Marine capture fisheries: Reforming and repurposing fishery subsidies, agreeing to sustainable quotas, and the replenishment and monitoring of fish stocks can all help prevent overfishing and depletion of fisheries wealth, especially impacting coastal communities.	Chapter 6			✔	
	• Mangroves: Return to investments in mangrove restoration and preservation should include both the value of the ecosystem services they provide to the economy and the value of produced capital they protect from floods and storm surges, especially as these risks are increasing with climate impacts.	Chapter 6	✔			
	• Agricultural land: Countries with significant shares of cropland wealth that are vulnerable to the impacts of climate change on crop yields should manage this risk by diversifying their portfolio, investing in other renewable assets and/or human or produced capital.	Chapter 5	✔			✔
	• Renewable energy: Countries, SNA, and SEEA should assign explicit values to renewable energy assets in national balance sheets, just as they currently assign values to fossil fuel reserves.	Chapter 14	✔			
Nonrenewable natural capital	• Fossil fuel–rich countries should manage the risks associated with global decarbonization and stranded assets via international cooperation and asset diversification, avoiding carbon-intensive downstream activities. Policy instruments might include energy taxation (or reducing energy subsidies) to better reflect environmental costs of fuels. This can also help manage external risks, such as border carbon adjustment taxes and other tariff and nontariff trade barriers to goods with a high environmental footprint.	Chapters 9, 10, 11		✔		✔
	• Resource rents from nonrenewable natural resources (especially oil, gas, and minerals) should be transparently collected and reinvested in sustainable forms of wealth—including public infrastructure, green produced capital, renewable natural wealth, and human capital (skills, health) to support sustainable prosperity.	Chapters 9, 11			✔	✔
Human capital	• Investing in girls' education can improve both the level and equity of human capital wealth. This may be particularly urgent in countries with overly unequal distribution of human capital, such as measured by CWON, including in some resource-rich countries.	Chapter 12		✔		✔
	• Investments in education and health, including policies and measures that reduce population exposure to air pollution, can enhance the value of human capital alongside improving well-being and productivity.	Chapters 7, 8, 12		✔	✔	
Produced capital	• Public capital (for example, infrastructure): Use proceeds from nonrenewable natural resources (oil, gas, and minerals) to invest in public infrastructure in capital-scarce countries.	Chapters 9, 11		✔		✔
	• Risks to the value of produced capital, such as infrastructure and cities, from storm and flooding can be mitigated by leveraging investments in nature, such as protective mangroves.	Chapter 6		✔	✔	
	• Proceeds from nonrenewables can be invested in produced capital and used to help improve the investment environment—a process known as "investing in investing," promoting both asset diversification away from dependence on nonrenewables and economic sustainability.	Chapters 9, 11		✔		
	• Fiscal policies should avoid unwarranted accumulation of produced capital in sectors exposed to transition risks and encourage accumulation of climate-proof produced assets.	Chapter 10		✔	✔	

Source: World Bank.
Note: CWON = Changing Wealth of Nations; SEEA = System of Environmental-Economic Accounting; SNA = System of National Accounts.

Note

1. *The Changing Wealth of Nations 2021* report, wealth accounts data, and other resources can be found at http://worldbank.org/cwon.

Reference

Dasgupta, P. 2021. *The Economics of Biodiversity: The Dasgupta Review*. London: HM Treasury.

Abbreviations

AIC	actual individual consumption
ANS	adjusted net savings
BAU	business as usual
BCAT	border carbon adjustment tax
°C	degrees Celsius
capex	capital expenditure
CCS	carbon capture and storage
CDR	carbon dioxide removal
CGE	computable general equilibrium
CO_2	carbon dioxide
CPL	climate policy leader
CSP	concentrated solar power
CWON	*Changing Wealth of Nations*
DALY	disability-adjusted life year
EIA	US Energy Information Administration
ESG	environmental, social, and governance
FAO	Food and Agriculture Organization of the United Nations
FERU	Fisheries Economics Research Unit (University of British Columbia)
FF	fossil fuel
FFDC	fossil fuel–dependent country
GBD	Global Burden of Disease Study
GDP	gross domestic product
GNI	gross national income
GNS	gross national savings
Gt	gigaton
GWh	gigawatt hour
HCI	Human Capital Index
HCP	Human Capital Project
I2D2	International Income Distribution Database
IAM	integrated assessment model
ICP	International Comparison Program
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change

km	kilometer
MCP	maximum catch potential
MENA	Middle East and North Africa
MER	market exchange rate
mt	metric ton
NDC	nationally determined contribution
NFA	net foreign assets
NPV	net present value
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics (UK)
PCA	principal components analysis
$PM_{2.5}$	fine particulate matter with a diameter of less than 2.5 microns
PPP	purchasing power parity
PV	photovoltaic
PWT	Penn World Table
RCP	Representative Concentration Pathway
RR	resource rich
RVM	residual value method
SAU	Sea Around Us (University of British Columbia)
SCC	social cost of carbon
SDGs	Sustainable Development Goals
SEEA	System of Environmental-Economic Accounting
SEEA-CF	System of Environmental-Economic Accounting—Central Framework
SNA	System of National Accounts
SSP	shared socioeconomic pathway
TFP	total factor productivity
WGI	Worldwide Governance Indicators

Executive Summary

Sustainability, Resilience, and Inclusiveness Are Urgent Challenges for Economic Development

The Changing Wealth of Nations 2021 provides an updated database and analysis of the world's wealth accounts spanning 146 countries, with annual data from 1995 to 2018. It also contains the widest set of assets covered so far, including the value of human capital broken down by gender, as well as many different forms of natural capital, spanning minerals, fossil fuels, forests, mangroves, marine fisheries, and more. The Changing Wealth of Nations (CWON) wealth accounts provide a rigorous, comparable monetary measure of these assets, grounded in the balance sheet approach based on both the System of National Accounts (SNA) framework and the System of Environmental-Economic Accounting (SEEA). This provides a rich set of economic indicators ready for use by a wide set of actors, including government and the private sector, to look beyond traditional measures such as gross domestic product (GDP).

Twenty-first century economic development challenges will be characterized by their complexity and interconnectedness with the natural environment. Climate change, loss of ecosystems, forests, and biodiversity; degradation of oceans and agricultural land; and different forms of pollution all threaten material well-being, including through potential "nonlinearities" and "fat tail" risks (Bolton et al. 2020).[1] To navigate these challenges, wealth accounts can broaden policy makers' lens beyond GDP; increasingly, experts and governments agree. For example, the Government of the United Kingdom commissioned the *Dasgupta Review* on the economics of biodiversity (Dasgupta 2021), which was released in early 2021 and has called for governments to embrace wealth measures, combining the value of produced capital, human capital, and natural capital.

Wealth and GDP are companions. When properly understood and combined, they provide the necessary guidance for managing economies more sustainably. However, on their own they are not sufficient for ensuring sustainability and human well-being, because they omit additional considerations of critical natural capital and social capital, among others.

But the disaggregated wealth accounts provide deeper insight to better guide policy choices than GDP alone. Increasing the value of renewable natural capital per capita, for example, contributes to sustainable development if it is done through better management and investments in nature. Essential conditions for value creation include—although are not limited to—policies that make the value of nature's services reflected in prices that economic agents and policy makers can see in the marketplace.

In addition, economic sustainability is not the same as human well-being. Wealth, like GDP, is intended to represent material well-being, not broader human well-being. Although per capita wealth may be similar for countries, the well-being of citizens may be quite different because of factors such as institutions, governance, culture, and social capital that influence but cannot be directly incorporated into monetary values. Furthermore, like other economic indicators, wealth measures reflect human-centered perspectives on value rather than an intrinsic or life-centered approach to valuation that is independent of utility to humans. Users of wealth accounts should therefore consider its strengths and weaknesses for policy applications (see box ES.1).

BOX ES.1 Strengths and Limitations of Wealth Accounting

The wealth accounting approach allows a wider set of assets to be considered than conventional public finance indicators, which normally focus on traditional capital assets and liabilities, such as machines, buildings, and infrastructure. The Changing Wealth of Nations converts a wider range of natural and human assets into monetary valuations while adhering to the System of National Accounts (SNA)–compatible balance sheet approach used in economic policy. This makes the more comprehensive spectrum of wealth visible and investment-worthy for economic and financial policy makers.

Comparable monetary measures of natural and human capital, alongside traditional forms of produced capital, allow economic policy makers to consider the impact on and benefits of these assets. This wider set of assets can be more easily included in policy making by ministries of finance, economy, and treasury and central banks. Wealth accounts can provide a yardstick that is comparable to their own metrics used to evaluate economic performance.

The benefits of adherence to the rigor of SNA-compatible balance sheets go hand in hand with the limitations of this approach. Some economic assets are more difficult than others to measure in market terms, especially natural assets, which may not have defined owners and readily observable market prices. Other entities, such as social capital (trust, institutions, and governance) and biodiversity are less amenable to the SNA-based balance sheet approach, as they can be seen as characteristics of assets rather than assets themselves. They are nonetheless essential to human well-being and enhance the value of more traditional assets as well as having intrinsic value beyond monetary considerations. The wealth accounts of natural capital do not provide a full picture of the management, accumulation, depletion, and degradation of ecosystems without complementary underlying biophysical indicators, such as measures of species loss or tree cover.

Further, the wealth accounts take asset prices as given by (or derived from) the existing markets. Therefore, they may not capture the "true" value of assets that are mispriced and/or mismanaged. Country policies,

(continued on next page)

BOX ES.1 Strengths and Limitations of Wealth Accounting *(continued)*

institutions, property rights regimes, and governance can distort the prices that buyers and sellers face in markets, failing to inform owners and users about the true value of an asset and often resulting in overharvesting and/or degrading asset value. Although all assets can be subject to market failures, it is a particularly serious problem for natural capital. Costs of fossil fuels or polluting factories fail to include external costs to society resulting in unconstrained damages from carbon emissions and local pollution. On the other side, many ecosystem services are not valued by markets at all, and if they are, the prices that users pay fail to reflect their benefits to food production, human productivity, clean water and air for people, livelihoods, tourism, and productive value chains. Market price distortions can vary over time within a country or across countries, even for an asset that is physically identical.

Many natural systems, such as the atmosphere or open oceans, do not have owners and property rights assigned. Therefore, their governance is subject to the "tragedy of the commons" (Hardin 1968; Ostrom 1990). Many negative impacts on assets are visible to markets only long after the critical ecosystems degrade, making them subject to the "tragedy of the horizon" as well (Carney 2015). These constitute additional limitations of relying on explicit market prices for the valuation of assets.

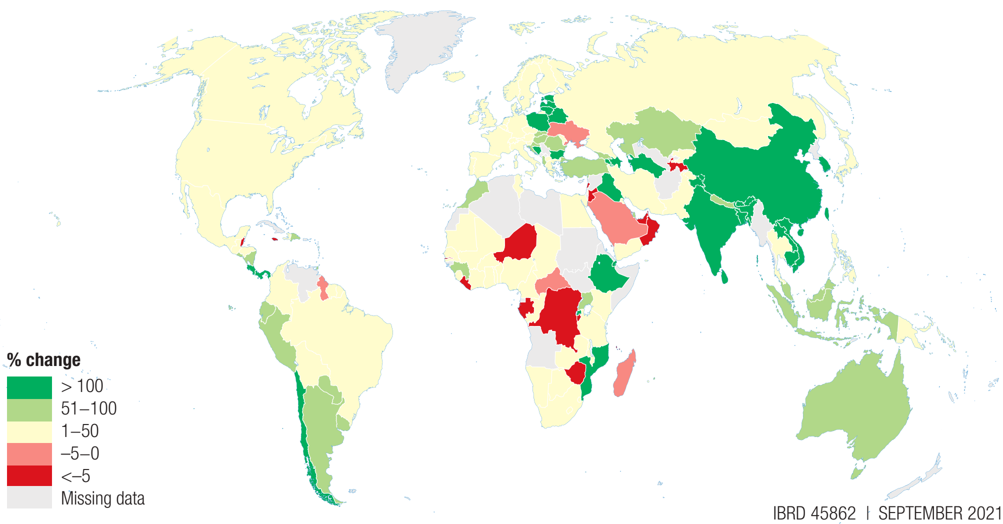
The good news is that over the past several decades the problem of unvalued and undervalued assets has been recognized, and tools for more accurately valuing nature or otherwise rewarding the ecosystem services that nature provides have been developed. Markets, including financial markets, are beginning to consider social costs and benefits of services that different assets provide. For example, while fossil fuel companies are facing divestment, companies producing clean technologies, energy, and electric vehicles are seeing rising stock prices. Several asset managers and investment banks have launched natural capital and environmental, social, and governance funds. They are betting on further developments in policy instruments to value and reward good stewardship of nature. Governments can therefore promote broader wealth creation and better management of assets by correcting for externalities with environmental fiscal reforms, creating direct regulations, establishing market payments for ecosystems' services, and signaling the direction of future policy.

Global and Regional Trends in Wealth

Global total wealth grew significantly between 1995 and 2018. All income groups saw increasing total wealth and per capita wealth over the period. However, for some countries the growth in total wealth per capita was disappointing, and even negative in some cases.

CWON 2021's measure of the change in wealth per capita over time is perhaps the most important metric to consider in addition to GDP and provides an actionable measure to track sustainability. Despite a global expansion in total wealth per capita between 1995 and 2018 (map ES.1), many countries are on an unsustainable development path, because their natural, human, or produced capital is being run down in favor of short-term boosts in income or consumption. In countries where today's GDP is achieved by consuming or degrading net assets over time, for example, by overfishing or soil degradation, total wealth is declining. This can happen even as GDP rises, because the practice undermines future prosperity rather than economic output today.

MAP ES.1 Growth of Total Wealth per Capita, 1995–2018



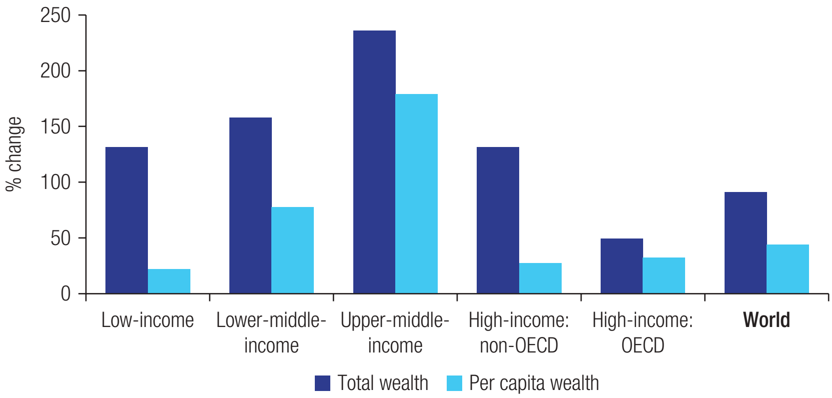
Source: World Bank.

The strongest performance was found among upper-middle-income countries, which had increases in wealth of over 200 percent between 1995 and 2018 (figure ES.1). Low-income countries saw per capita wealth growth by less than the global average, at 22 percent compared with 44 percent. This means that low-income countries are falling further behind the rest of the world, creating a significant divergence in global wealth per person. Per capita wealth changes are consistently lower than total wealth growth, as they factor in the rate of population growth, which for some countries has been very rapid during this period.

Economic development cannot be socially sustainable if it is not inclusive. Inclusiveness across countries requires the poorest countries to catch up with the per capita wealth of the rest of the world. To do so, however, they will need an above-average rate of growth in assets—to ensure that they catch up and then keep pace with higher levels of population growth. Doing so would mean their share in global total wealth would be rising. Unfortunately, the data show that this is not happening quickly. Between 1995 and 2018, low-income countries' share of global wealth increased only from 0.5 to 0.6 percent. The performance of lower-middle-income countries was better, increasing in share from 5 to 7 percent by 2018. China's performance was the most striking, as its share of global total wealth transformed from a modest 7 percent in 1995 to 21 percent by 2018.

Although national total wealth increased everywhere, per capita total wealth did not. Twenty-six countries saw a decline or stagnation in per capita wealth as population growth outpaced net growth in asset value, especially in Sub-Saharan Africa among countries such as the Democratic

FIGURE ES.1 Changes in Total Wealth and Per Capita Wealth, by Income Group, 1995–2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

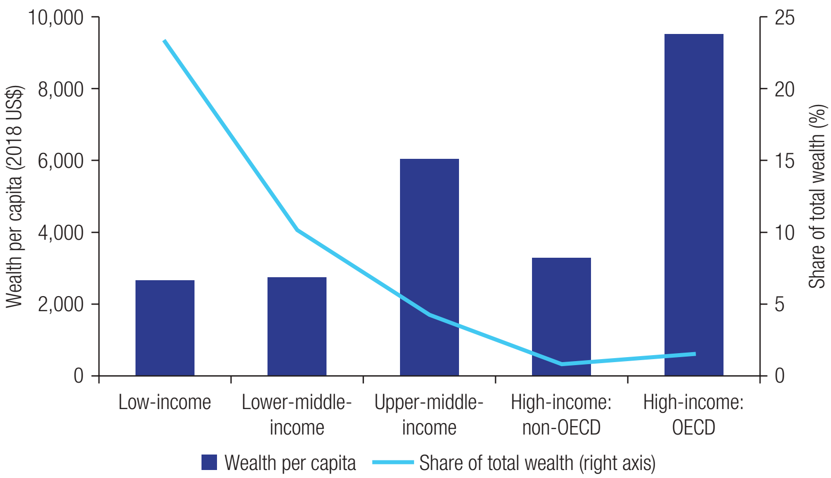
Republic of Congo, Niger, and Zimbabwe. These twenty-six countries could be found in all income groups. As per capita wealth declines, the ability of countries to maintain per capita income will decline. If the trend continues, future generations in these countries will be worse off than current generations.

Natural Capital

Renewable natural capital (forests, mangroves, fisheries, agricultural land, and protected areas) has increased in value since 1995 globally and among all income groups. It remains critically important for low-income countries, accounting for 23 percent of their total wealth in 2018 (figure ES.2). This share is almost half of what it was in 1995 (39 percent), as these countries invested and diversified their asset portfolios by building the value of human capital and produced capital. Renewable natural assets nonetheless remain important even as countries grow and develop. While the share of renewables in total wealth falls with income, the per capita values are highest in high-income Organisation for Economic Co-operation and Development (OECD) countries. This pattern shows that the route to prosperity need not come at the expense of nature—the opposite is true.

Enhancing and protecting renewable natural capital to increase its value has been a part of the sustainable development path of higher-income countries. CWON 2021 data show countries can avoid pursuing short-term growth of GDP at the expense of natural capital. Instead, sustainable development is better achieved by responsibly managing natural assets and using the proceeds from nature to support investment in human and produced capital.

FIGURE ES.2 Renewable Natural Capital, by Income Group: Wealth per Capita Value versus Share of Total Wealth, 2018

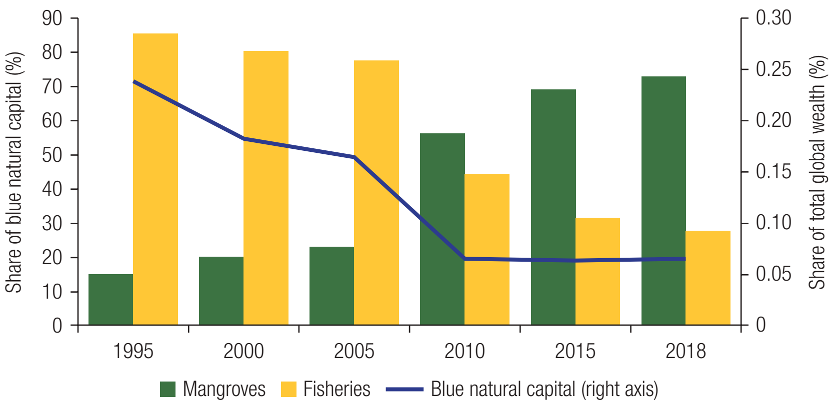


Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

CWON 2021, for the first time, presents accounts for major components of blue natural capital: mangroves and marine capture fisheries, which are a critical part of total wealth for some countries. Here, the performance has been mixed. Blue natural capital fell by half from 1995 to 2018, as the value of fisheries collapsed by 83 percent, and this was only partially compensated by an increase in mangrove asset value of 157 percent (figure ES.3). The relative importance of mangroves and marine capture fisheries in blue natural capital reversed over time: the fisheries share declined from 85 to 27 percent of blue natural capital, while mangroves grew and became the dominant component of blue natural capital considered in CWON accounts. In all regions except South Asia, the value of fisheries declined, while the value of mangroves increased in all regions except North America. The main reason for the decline in the value of fisheries is a physical depletion of fish stocks due to the failure to coordinate fishing activities between countries and the private sector. The value of aquaculture has not been taken into consideration while calculating blue natural capital.

The global wealth of mangroves has increased since 1995, but their physical area declined in the same period. The reason is that the value of coastal human structures that mangroves protect has dramatically increased. In line with SEEA/SNA methodology, a major part of the value of mangroves is derived from the market value of buildings, roads, and other physical infrastructure along the coast that mangroves protect from storm and tidal surges. Had their physical area also expanded alongside the value of human coastal infrastructure, far more wealth creation

FIGURE ES.3 Shares of Mangroves and Fisheries in Blue Natural Capital, and Share of Blue Natural Capital in Total Wealth, 1995–2018



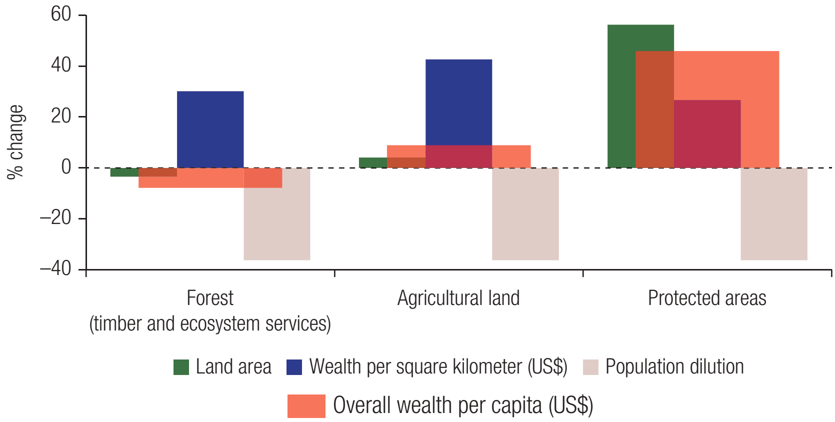
Source: World Bank staff calculations.
Note: Blue natural capital is the sum of mangrove assets valued for coastal protection services and marine capture fisheries.

would have occurred. This analysis unveils the economic benefits of government policies to facilitate physical protection and expansion of mangroves.

Low- and middle-income countries, where land accounts (forests, protected areas, and agricultural lands) are a large component of total wealth, have seen declining forest wealth but rising agricultural wealth. While forest wealth (timber plus ecosystem services) per capita decreased by 8 percent between 1995 and 2018, driven by population growth and a loss of forest area, agricultural land wealth (cropland plus pastureland) per capita has increased by 9 percent due to area expansion and increasing value per square kilometer (figure ES.4). The area in agriculture increased by 4 percent between 1995 and 2018, while forest land area declined by 4 percent overall, due to conversion to agriculture and other land uses. Although wealth in agricultural lands increased over 1995–2018, the simulations of future impacts of climate change shows that this trend may be slowed or even reversed because of changes in temperature, precipitation, and land degradation. Protected areas show a rapid increase in area and wealth per square kilometer, which is promising news for the sustainability of human development.

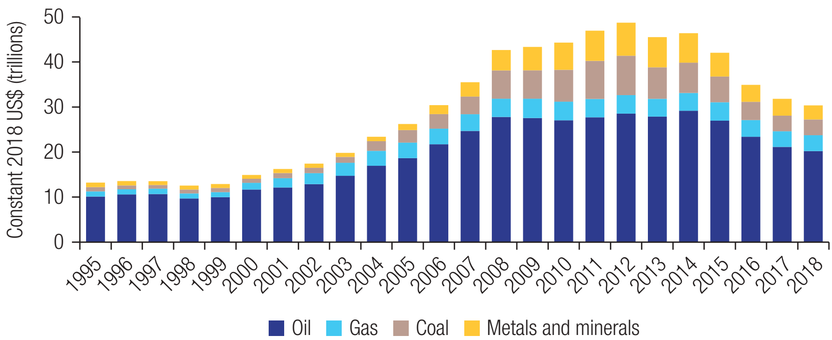
Nonrenewable natural capital grew rapidly from 1995 until around 2014 and has declined in value since then, driven by falling prices (figure ES.5). Between 2014 and 2018, nonrenewable total wealth fell from US$46 trillion to US$30 trillion (a 35 percent decline in four years). This significant loss in value highlights the difficult development challenges faced by countries that depend on these assets, particularly where price changes are exogenous shocks falling outside the control of government policy or domestic company decisions.

FIGURE ES.4 Forests, Agricultural Land, and Protected Areas: Change in Land Area, Wealth per Square Kilometer, Population Dilution Effect, and Overall Wealth per Capita in Low- and Middle-Income Countries, 1995–2018



Source: World Bank staff calculations.

FIGURE ES.5 Global Nonrenewable Natural Capital, 1995–2018



Source: World Bank staff calculations.

What Drives Changes in Asset Value?

The value of assets is a combined effect of changes in the physical volumes of assets and their unit rents (market revenues minus costs). Information on changes in physical volumes are essential from the point of view of a *strong* approach to environmental sustainability, which requires additional attention paid to the limits to substitution between natural and other forms of capital, including planetary environmental boundaries, thresholds in critical ecosystems services, as well as irreversibility of some uncertain effects of potential collapse of some forms of natural capital. CWON 2021 introduces for the first time a transparent decomposition analysis to disentangle the physical volume and market price effects on natural asset values.

TABLE ES.1 Three-Part Decomposition Results for Natural Capital Stocks, 1995–2018

constant 2018 US$ (millions)

	1995	Rent effect: Volume effect	Rent effect: Unit rent effect	Lifetime effect	2018
Natural capital	38,409	22,120	5,381	–1,370	64,542
Renewable natural capital	25,776	9,456	2,013	–1,660	35,586
Forests, timber	2,544	239	99	–154	2,728
Forests, nontimber	4,879	91	2,487	0	7,458
Mangroves	213	–13	348	0	548
Fisheries	1,225	62	–1,080	0	207
Protected areas	1,927	971	849	0	3,747
Cropland	10,631	6,018	–456	–1,506	14,687
Pastureland	4,356	2,088	–233	0	6,211
Nonrenewable natural capital	12,633	12,665	3,368	290	28,956
Oil	9,588	6,345	3,363	–188	19,108
Natural gas	1,090	1,695	559	–55	3,288
Coal	949	2,150	383	0	3,482
Metals and minerals	1,007	2,475	–937	533	3,078

Source: World Bank staff calculations.

Note: Because the volume effect (in dollars) is weighted by unit rent, this can be positive even if physical quantities (e.g., catch in tons) show a negative trend. Moreover, the global volume effect shown here can be dominated by large countries. Green and pink cells represent positive and negative effects on natural capital, respectively.

Table ES.1 shows the three-part decomposition for natural capital assets from 1995 to 2018. The decomposition shows the contribution of each factor to this change. Overall, the value of natural capital increased by 68 percent, with renewables increasing by 38 percent and nonrenewables increasing by 129 percent.

Decomposition analysis can highlight striking changes hidden in headline wealth trends. Mangroves, as discussed, have declined globally in area but have risen in overall value. Had their area also expanded, far more wealth creation would have occurred—measured via the protective benefits from mangroves.

Unit rent effects (prices and costs) matter as well. Volatility in fossil fuel prices played a major role in fluctuations of values of oil, gas, and coal wealth. The declining unit rents for metals and minerals reflects, in part, the lower prices toward the end of the time period. This meant that despite increases in volume from additional production, and expansion of reserves reflected in lifetime effects, weakening commodity prices significantly reduced the potential growth in mineral wealth around the world. These reduced unit rents have had systemic macrofiscal consequences in countries that are highly dependent on metals and minerals for exports and government revenues.

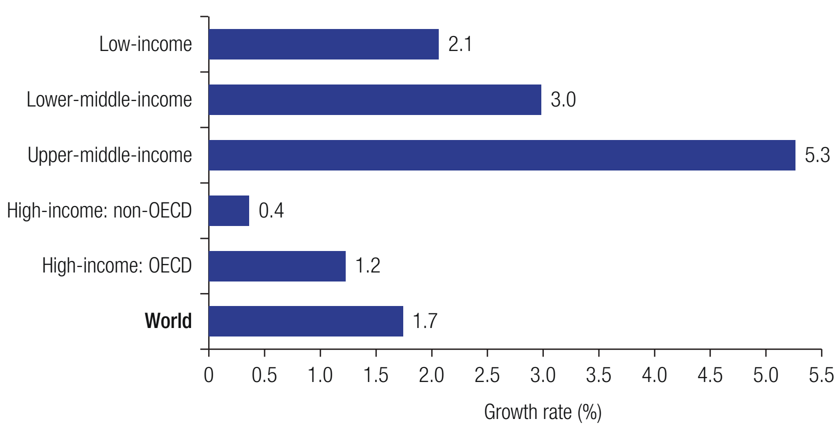
Human Capital

Human capital—estimated as the present value of future earnings for the labor force, employed and self-employed—is the largest asset across all income groups, constituting 64 percent of total wealth in 2018, only slightly higher than in 1995. Self-employed workers account for 13 percent of global human capital but a much larger share of the total in many low-income countries, where the agriculture sector and informal employment are significant. CWON 2021 provides human capital accounts broken down by gender. Significant disparity between male and female human capital persists across most regions and income groups, with great variation among regions: females hold 44 percent of human capital in Latin America and the Caribbean but only 13 percent in South Asia. Human capital per capita is growing fastest in upper-middle-income countries, at an annual rate of 5.3 percent, while growth in OECD countries is slower than the global average (figure ES.6).

The CWON 2021, for the first time, calculates human capital using region- and income group–specific future wage growth rates, making an important stride in improving the estimates of human capital. The slower annual wage growth in high-income countries (roughly 1 percent), combined with the aging of the labor force, reduces their share of global human capital. Meanwhile, higher rates of wage growth in some middle-income countries (up to 4 percent) increases their relative share.

Population health, education, and skills are embedded in the CWON methodology of human capital valuation via estimated lifetime earnings. Although the full, long-lasting effects of the COVID-19 pandemic are still unknown, the resulting economic downturn and associated unemployment and loss of earnings have already set back the long-term progress in poverty reduction, especially in low-income countries. When the

FIGURE ES.6 Annual Growth Rate of Human Capital per Capita, by Income Group, 1995–2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

pandemic's downward impact on future wage growth is incorporated into the estimation of human capital, low-income countries experience the largest negative impact, with a loss of 14 percent of total future human capital compared to the value in 2018. At the regional level, Sub-Saharan Africa and South Asia suffer the greatest setbacks, losing 15 and 7 percent of human capital, respectively. CWON 2021 also includes estimates of losses of human capital due to air pollution.

Policies to Manage Risk and Build Energy Wealth for the Future

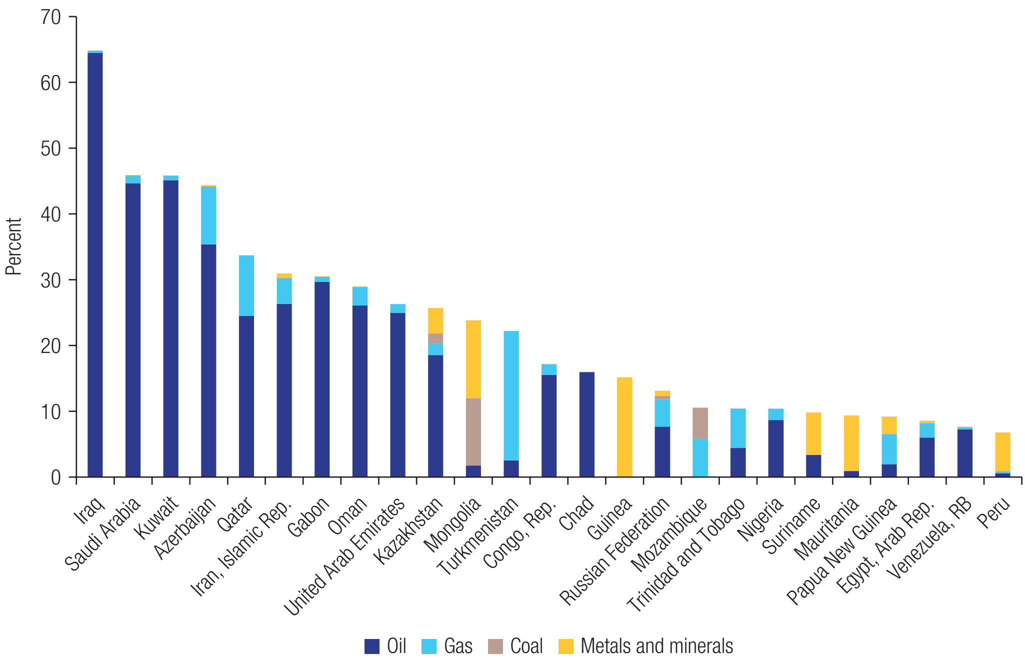
Primary energy resources, such as renewable energy and fossil fuels, are important components of natural capital and should be accounted for as part of the wealth accounts. So far, from these, only subsoil nonrenewable fossil fuel assets are included in the national balance sheets and in the CWON wealth accounts. The measurement of renewable energy resources—wind, solar, and hydropower—as assets has not been systematically addressed in the SNA or the SEEA. This edition of the CWON demonstrates how to account for renewable energy wealth in the same way as for fossil fuels.

The global low-carbon transition is already rebalancing the national portfolios of energy assets. If the goals of the Paris Agreement are achieved, the value of fossil fuels will be lower and the value of renewable energy will increase. But there is deep uncertainty about how exactly the low-carbon transition will unfold. Policies can also shape the evolution of this portfolio and levels of investment in the different assets. The CWON 2021 explores these risks and opportunities for energy assets and how the uncertainty can be navigated by getting the right prices and policies.

Countries that are well endowed in nonrenewable energy reserves (figure ES.7) saw significant growth in wealth over 1995–2014, albeit with considerable volatility. From 2014, global prices and associated rents from fossil fuels declined precipitously and have not fully recovered. The COVID-19 shock in 2020 has suppressed prices again. Historical changes to nonrenewable natural capital wealth are decomposed by their contributing factors, such as depletion and discoveries, changes in prices and costs, and other factors. The CWON analysis explores the challenges facing countries that are dependent on nonrenewable natural capital and highlights that the urgent low-carbon transition represents a significant risk to fossil fuel assets and the countries that rely on them.

Simulations of several potential global low-carbon transition pathways show that transition risk can significantly affect the value of all fossil fuel assets, and that the impact will be unevenly distributed across fuels, countries, and asset owners. Distributions of risk will also significantly depend on the pathway along which the low-carbon transition will unfold. CWON 2021 unpacks the risk to the value of fossil fuel assets and explores it quantitatively by applying a macroeconomic model to run multiple climate and trade policy scenarios. From 2018–50, if the Paris climate ambitions are achieved, global fossil fuel wealth may be US$4.4 trillion to

FIGURE ES.7 Nonrenewable Natural Capital Assets' Share of Total Wealth, by Highest-Share Countries, 2018

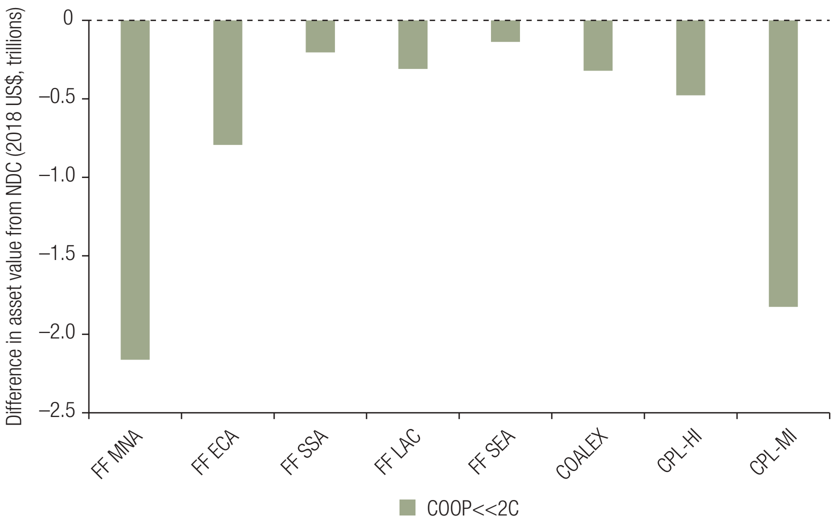


Source: World Bank staff calculations.

US$6.2 trillion (13–18 percent) lower than under a business-as-usual scenario. Oil assets represent the largest value at risk and gas the lowest, but in percentage terms coal reserves would lose most of their reference value and oil the least. By country group, the highest value at risk is held by fuel exporters in the Middle East and North Africa because of their significant oil exports, and by the middle-income high fossil fuel users (including China and India) because of their high coal reserves and use (figure ES.8). Ambitious climate policies have large implications for coal wealth but do not represent a systemic macrofiscal risk to coal-intensive countries, because even for the largest producers, coal wealth accounts for a much smaller share of total wealth. However, managing the risks of stranded miners, stranded regions, and stranded coal power plants may be a significant challenge. The share of oil or gas in the total wealth among major producers of each is much higher than coal and poses significant macroeconomic risk if a managed transition away from fossil fuel dependence is not achieved.

Oil exporters have incentives to adopt their own climate policies in cooperation with international mitigation efforts. CWON modelling suggests that oil assets could lose more value if unilateral climate actions to achieve the goals of the Paris Agreement are undertaken by oil importers

FIGURE ES.8 Risk to Fossil Fuel Wealth in the Most Ambitious (COOP<<2C) Climate Policy Scenario, by Region



Source: World Bank staff simulations with ENVISAGE.
Note: COALEX = major coal exporters; COOP<<2C = cooperative climate policies consistent with the 2°C target of the Paris Agreement; CPL-HI = high-income climate policy leaders (net fuel importers); CPL-MI = low- and middle-income climate policy leaders (net fuel importers), including China and India; ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); LAC = Latin America and the Caribbean; MNA = Middle East and North Africa; NDC = nationally determined contribution; SEA = Southeast Asia; SSA = Sub-Saharan Africa.

alone. Gas and coal exporters may have less incentive to take early climate policy action. Macroeconomic adjustments in the global economy may encourage them to "free ride" on the unilateral climate mitigation efforts of the rest of the world and benefit from attracting and retaining emission-intensive industries using gas and coal as inputs. Border carbon adjustment taxes can alter these incentives, but they would further decrease the value of fossil fuel assets. The analysis conducted in this report identifies strategies to encourage climate cooperation between fuel importers and exporters and to manage the risk of stranded fossil fuel assets while promoting cleaner sources of sustainable growth.

Many of the world's lower-income countries, including those that are fragile and affected by conflict, are also reliant on fossil fuels. Such countries rely heavily on the proceeds from fossil fuel production and exports and have not yet converted their subsoil energy assets into a diversified portfolio of national wealth, especially internationally competitive produced capital. These countries need to harness the rents from their nonrenewable resources to accumulate produced and human capital in sustainable and tradable economic activities. The low-carbon transition increases the urgency of this task, but the historical record is poor. Technology and financial cooperation will be essential to support a low-carbon transition for these countries.

Just like fossil fuels, hydropower, solar, and wind energy should be assigned an explicit asset value in the national balance sheets. So far, they are not included. CWON 2021 argues that the value of renewable energy as natural capital is not reflected in the value of produced capital (such as power generation plants) or the value of land used to generate renewable electricity. Leaving renewable energy assets out of the national balance sheets misses a great deal of emerging wealth. Experimental calculations of renewable energy asset values for 15 countries for 1990–2017 show that the value of hydropower assets already matches the value of fossil fuel assets in some countries (for example, Brazil and Canada). As in other nascent industries, solar and wind energy had yet to create significant wealth for nations in 2017 (the last year for which consistent data series were available), even though renewable power plants generated profits in many markets, often with the help of subsidies. With rapidly declining costs, solar and wind resource rents are quickly approaching positive values. However, total renewable energy wealth had been declining until 2017 (figure ES.9, panel a) because the rate of growth of the volume of renewable electricity generation has outpaced the speed at which rents per unit of produced electricity are approaching positive values (figure ES.9, panel b).

The critical policies that can increase asset values include making electricity markets more competitive by removing protection of existing

FIGURE ES.9 Renewable Energy Wealth and Energy Generation in 15 Major Producing Countries, 1990–2017

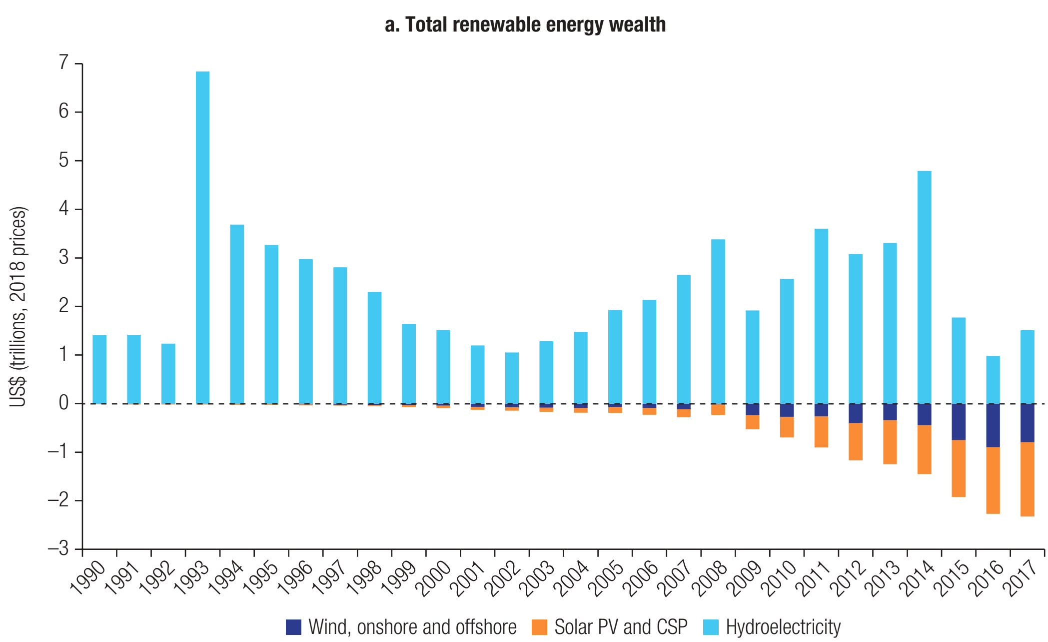


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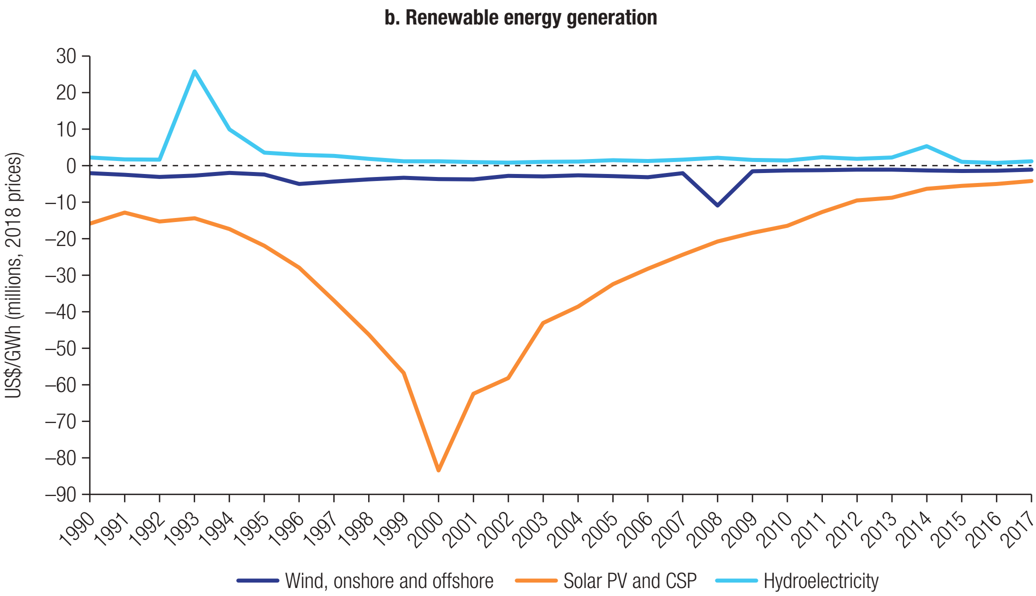
FIGURE ES.9 Renewable Energy Wealth and Energy Generation in 15 Major Producing Countries, 1990–2017 *(continued)*



Source: World Bank staff calculations.
Note: Negative values are illustrative only, portraying distance between present status and actual contribution to wealth. CSP = concentrated solar power; GWh = gigawatt hour; PV = photovoltaic.

thermal plants from early retirement and by levelling the playing field by pricing carbon emissions. These policies can make clean energy not only profitable to operators of power plants, but also wealth-creating for society without requiring subsidies. Current technologies can make clean energy profitable and create wealth, and with the right policies the value of renewable energy sources will begin to exceed those of fossil fuel assets.

Wealth Accounts as a Tool for Macroeconomic Policy and the Financial Sector

The CWON 2021 presents new analysis that shows different ways in which policy makers can better manage economic sustainability, diversification, and fiscal sustainability. One example is to use information on the evolution of different assets to see early warning signs of unsustainable growth. For example, degradation in the value of renewable natural capital has been associated with lower or declining total wealth per capita over time. Meanwhile, countries that are protecting and enhancing the value of natural assets and hence where values of renewable natural capital are rising have seen better economic performance overall. Traditional measures of economic performance conceal the impact that the different sources of GDP growth are having on degrading or enhancing the human and natural capital base for future prosperity. Measures from CWON, such as changes in wealth per capita and the adjusted net savings indicator, can provide rigorous yardsticks for policy makers. Diving deeper into the evolution of individual asset values over time provides even greater resolution into the sources of sustainable and unsustainable development.

Abundance of nonrenewable natural capital raises special challenges for economic sustainability. This is because rents—and the revenues government raise—are derived from depleting the assets. Furthermore, in addition to the traditional depletion effect, the value of fossil fuel rents is increasingly under pressure as the global economy decarbonizes. This means that fossil fuel wealth can shrink even if reserves are not depleted. Fiscal sustainability should therefore consider fossil fuel rents as an inherently unsustainable source of revenues. Macrofiscal prudency suggests that a large share of the remaining revenues from fossil fuels should be used to accumulate other sustainable assets, such as human capital and green physical infrastructure, and to enhance the value of renewable natural capital. Resource-rich countries have struggled to do this—they have on average a more negative measure of adjusted net savings compared with non-resource-rich countries. Asset diversification (Gill et al. 2014; Peszko et al. 2020)—the process of accumulation of a broad range of productive assets, to reduce dependence on fuel extraction and fuel-intensive manufacturing products—can be a pathway to sustainable prosperity, and the CWON indicators can provide a means for measuring such progress.

Few resource-rich countries have managed to achieve even traditional economic diversification, let alone asset diversification. Producing and exporting large quantities of nonrenewable resources can constrain the rest of the economy—a phenomenon known as the Dutch disease. Resource exports make it difficult to build value in other export sectors due to local currency appreciation leading to increased local costs. CWON 2021 presents evidence that the average level of human capital per capita is lower in resource-rich countries compared with non-resource-rich countries. CWON 2021 finds that the distribution of human capital between men and women in resource-rich countries is more unequal compared with non-resource-rich countries and that human capital is more skewed toward the public sector.

The CWON and wealth accounting can help financial markets assess the utility of environmental, social, and governance (ESG) frameworks as part of decision-making for sustainable development. Wealth data are uniquely suited to inform sovereign ESG scores because the wealth accounts put a dollar value on resources, adopt a forward-looking perspective, and have a long history of curated data that is comparable across 23 years and 146 countries. As wealth accounting reflects the natural resource's long-term economic benefits, it can complement purely environmental indicators for decision-makers. Adoption of the wealth data has been constrained by their five-year frequency and late availability. The new wealth data in this edition of the CWON (see box ES.2) raise the updating frequency to annual. Econometric and machine-learning methods, combined with new remote-sensed data sources, can in the future help increase the wealth data to higher frequencies and subnational resolutions. This will allow for new applications of the wealth accounts.

BOX ES.2 What's New in CWON 2021?

Expanded Coverage of Natural Capital

This edition of the CWON expands the coverage of natural capital by including components of blue natural capital in the core wealth accounts for the first time. Blue natural capital includes the accounts for marine fisheries and mangroves, which are valued for their coastal protection service, filling an important data gap in renewable natural capital. CWON 2021 also advances the rigor of asset valuation for forest ecosystem services, timber, agricultural land, and minerals, resulting in improved estimates of countries' natural capital. CWON 2021 includes analysis of the impact of air pollution exposure on human capital through premature mortality, making the important link between environmental health risks and the accumulation of human capital. It also explores and pilots approaches for including additional asset classes in future editions of the CWON, for example, renewable energy and biosphere, at least through its climate regulatory services.

Expanded Wealth Account Data

CWON 2021 estimates wealth data for 146 countries for the years 1995 to 2018 in market exchange rates, accompanied by policy analysis to help guide policy makers in managing their nation's wealth for sustainable prosperity. The analysis finds a critical role for governance at both national and international levels in shaping the wealth of nations, and therefore a vital role for collective action to safeguard our future prosperity.

The wealth accounts are grounded in the concepts and framework of the System of National Accounts (SNA) 2008 (EC et al. 2009) and its extension for natural capital, the System of Environmental-Economic Accounting (SEEA) Central Framework (UN et al. 2014a), and the SEEA Ecosystem Accounts (UN 2021; UN et al. 2014b). Although there has been experimentation with human capital, it is not yet part of the SNA national balance sheet.

For the first time, the CWON 2021 includes decomposition analysis of what has driven changes in wealth. For example, for fossil fuels and minerals, it examines whether changes in wealth were driven more by changes in prices, costs, production, and reserves or by other factors. Future work will seek to expand this decomposition analysis and make it more widely accessible for users.

Use of the Wealth Accounts for Policy

With substantial progress in measurement, CWON 2021 applies the lens of wealth to the analysis of asset portfolio management under risk and uncertainty. CWON 2021 does not attempt to predict the impact of rare and unexpected events that have potentially extreme or wide-ranging impacts, and which may be more frequent with expected environmental crises, such as climate change and biodiversity loss, and surprises such as the COVID-19 pandemic. Instead, CWON 2021 helps understand and navigate uncertainty by providing scenarios that explore future wealth under several possible scenarios of climate change and climate policies. For human capital, CWON 2021 explores the impact of the COVID-19 pandemic and air pollution. For fossil fuels, the scenario analysis identifies policy pathways to manage the risks of stranded assets through cooperative and noncooperative low-carbon growth strategies and border carbon adjustment taxes. CWON 2021 also explores how policy reforms can enhance wealth creation from natural capital such as fisheries and renewable energy.

Conventional measures of fiscal sustainability overlook important wealth considerations, such as the depletion and degradation of natural capital. Comprehensive wealth accounts can shed light on the sustainability of fiscal policies and management. For example, the source of government revenues may be unsustainable if it comes from extraction of nonrenewable assets, such as fossil fuels, or if it comes from an asset that is being mismanaged,

(continued on next page)

BOX ES.2 What's New in CWON 2021? *(continued)*

such as taxation of an overfished fisheries sector. By introducing information on the assets underlying government revenue sources, the wealth accounts can help guide more sustainable policy making, including via fiscal management.

Comparison of Wealth across Countries Using Purchasing Power Parities and Market Exchange Rates

For the first time, CWON 2021 looks at the unequal distribution of wealth across countries using purchasing power parities (PPPs) in addition to market exchange rates (MERs). MERs have limitations for understanding how material well-being varies across countries, because one US dollar can purchase different amounts of goods and services across countries. While this analysis is still experimental, the initial results show that South Asia's share of PPP-based global wealth is 2.3 times higher than in MERs in 2018, and Sub-Saharan Africa's PPP-based share almost doubles. Looking at inequality across income groups, the MER-based total wealth per capita of the OECD in 2018 was 58 times greater than the low-income country average—but this gap narrows to 21 times when valued in PPPs.

Looking Ahead

While CWON 2021 has made significant progress, much work remains to be done. This edition includes pilots and discussion of where it is feasible to expand wealth coverage in future editions and to make wealth accounts even more comprehensive.

Renewable energy and water should be added to the core CWON accounts, depending on data availability. This volume provides a proof of concept that renewable energy can be part of the national balance sheets and develops experimental renewable energy accounts for a sample of 15 countries.

Although the analysis considers the potential impacts of climate change on asset value, CWON does not yet include the value of carbon retention or sequestration services as part of wealth embedded in biological ecosystems (for example, forests, soils, and oceans). Nor does it subtract the social cost of carbon from fossil fuels. There are ample cross-country data available to measure physical carbon balances but no final agreement about how to account for the value of climate regulation services in the SEEA.

The CWON team will pursue opportunities to capture how social capital and biodiversity influence the value of assets in the core accounts. These advances are somewhat different in nature. Biodiversity and social capital are what Dasgupta (2021) refers to as enabling characteristics of assets, a quality that gives value to other assets, rather than assets as such. Social capital may not easily be made part of the core monetary accounts, but new techniques to measure social capital can provide essential, complementary indicators to changes in total wealth per capita. Chapter 15 in this volume takes stock of what we know about measuring the economic implications of social capital. Further analytical work may illuminate how social capital adds value to national balance sheets.

The future work program for CWON will also consider how to better reflect the importance of biodiversity and critical natural capital in the analysis. For example, wealth accounts currently do not fully capture the impact on renewable natural capital where losses and degradation have brought ecosystems to the point of potentially irreversible thresholds, which may precipitate catastrophic events on a scale that escapes the conceptual apparatus of traditional economics. The CWON accounts have provided new ways to measure sustainability in the context of material well-being. However, changes in wealth per capita provide only a measure of "weak" sustainability that implicitly assumes a high degree of substitutability among different asset classes. The emergence of multiple global crises, such as biodiversity loss, climate change, and ocean pollution, is a strong wake-up call about the limits to replacing critical ecosystem services with human-made substitutes.

To date, the CWON accounts have reported measures of wealth at the national level and at annual time intervals. However, improvements in data, including via remote sensing methods, open possibilities for greater spatial and temporal measurement of wealth. Future editions of CWON may be able to explore increased spatial and temporal granularity to meet the needs of different stakeholders, especially investors and financial markets, and to improve the targeting of policy interventions for sustainable wealth management. For example, by breaking down the wealth accounts at subnational levels of analysis, policy makers can see how unequal the distribution of wealth and different assets is across the country, and how that has evolved over time. Enhancing the valuation of some assets to monthly or even daily reporting could support new applications and analysis, such as those in the financial sector, which typically utilizes high-frequency information.

Limitations in the estimates of produced capital and human capital may be addressed in future editions. It would be useful to disaggregate produced capital by public and private sectors, and International Monetary Fund estimates (IMF 2019) could be incorporated in future editions of the CWON. Another improvement could include reflection of the impact of natural catastrophes on the value of produced assets. Produced capital is measured as the sum of investment minus normal depreciation, and its value is not routinely adjusted in national balance sheets for losses from catastrophic events. A study by the United Kingdom's Office for National Statistics (ONS 2019) finds that normal depreciation rates that have been in use for many years do not reflect current depreciation, which is accelerated by the impacts of climate change. The study suggests revision. Others have called for a review of what are considered normal depreciation rates in light of the impact of climate change, which is becoming the "new normal."

CWON 2021 describes some of the main findings emerging from the new, expanded wealth accounts—the most comprehensive and SNA-compatible wealth accounts available so far. The analysis and the abundance of data—which are available online—should generate new questions about development, the dynamics of how countries accumulate wealth, and how to promote efficient, equitable, and sustainable use of wealth. Sustainability into the 21st century will depend on building and managing a much broader asset base than the one that galvanized progress since the industrial revolution. New challenges require new concepts, data, and tools in economics. CWON 2021 proposes some of them.

Note

1. A nonlinear change is one that is not based on a simple proportional relationship between an independent variable and a dependent variable. Nonlinear phenomena often show unexpected changes that are difficult to predict. Tail risks are the events with potentially catastrophic consequences but small probabilities of occurring. When tails grow fat it mean that these probabilities increase (Weitzman 2014).

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PART I

Global, Regional, and Country Trends in Wealth, 1995–2018

1

The Wealth of Nations

Glenn-Marie Lange, James Cust, Diego Herrera, Esther Naikal, and Grzegorz Peszko

Main Messages

- Wealth accounts are a necessary complement to gross domestic product (GDP) and other traditional economic measures because they reflect the state of assets that produce GDP.
- Wealth accounts provide an indicator, change in wealth per capita, that offers insight into whether growth will be sustainable in the long term and whether investments in human, produced, and natural capital are sufficient to keep pace with population growth and a country's development aspirations.
- *The Changing Wealth of Nations* (CWON) *2021* provides the most comprehensive set of global annual wealth accounts for 146 countries, from 1995 to 2018.
- This edition of the CWON significantly extends and improves the coverage of natural capital and monitors its trends in order to inform the debate on the environmental dimension of sustainability. New work demonstrates how wealth accounts can be used for policy and applies scenario analysis for asset valuation to inform decision-making under uncertainty.

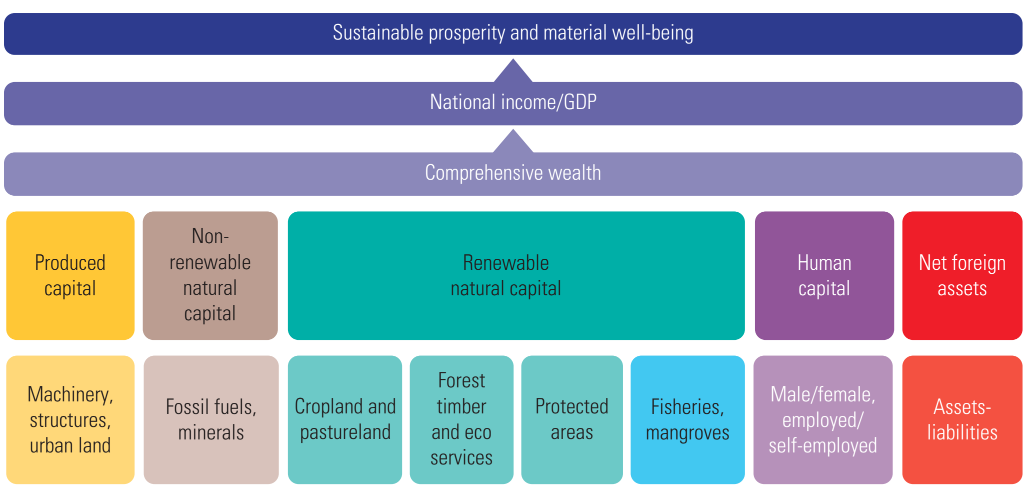
Why Measure Wealth?

The starting point, as in the previous editions of the CWON, is that a nation's income is generated by its wealth, measured comprehensively to include all assets: produced, human, and natural capital (renewable and nonrenewable). Sustained economic growth over the long term requires building and managing this broad portfolio of assets. Although a macroeconomic indicator like GDP is an important indicator of economic activity, it is a flow measure that captures income or production over a period but does not reflect changes in the underlying asset base. Hence, used alone, GDP may provide misleading signals about the state of the economy, the efficiency of asset utilization, and the sustainability of development. GDP does not reflect depreciation, depletion, and degradation of assets.[1] It does not indicate whether accumulation of wealth keeps pace with population growth or whether the mix of different assets will support a country's development goals.GDP indicates whether an economy is growing, but wealth indicates the prospects for long-term economic growth (figure 1.1). Economic performance is best evaluated by monitoring both GDP and wealth.

One can see the usefulness of this approach by comparison with firms or households. If a firm wants to raise money from potential investors, it must report both its annual income statement and its balance sheet.[2] The income statement alone is not sufficient, because a firm can increase its income simply by selling off its assets. But this is a short-term strategy that cannot be maintained and undermines the long-term financial viability of the firm. Similarly, when applying for a mortgage or other loans, households must reveal their income and the sum of assets minus liabilities to provide a complete picture of financial health. Although the same principles should apply to national economies, countries regularly report only their national income, or GDP. Few regularly compile national balance sheets. Both GDP and national wealth accounts are needed for an accurate picture of the financial health of nations and their prospects for long-term development.

The World Bank established a program for measuring national wealth to monitor long-term economic well-being and guide the development process through the lens of a country's portfolio of assets (box 1.1). The first edition of the CWON, *Where Is the Wealth of Nations? Measuring*

FIGURE 1.1 Structure of Comprehensive Wealth Accounts



Source: World Bank.

BOX 1.1 Sustainability and the Wealth of Nations

The World Bank first introduced the concept of wealth underpinning national income, and long-term prosperity as dependent on wealth, in the 1990s. *The Changing Wealth of Nations* (CWON) developed the argument for a new metric of sustainability for economic development—the *change in wealth per capita*—and demonstrated its usefulness in many applications. *Nondeclining wealth per capita* is an indicator based on the original definition of sustainability from the *Our Common Future* report, also known as the Brundtland Report (World Commission on Environment and Development 1987). (Prior to the CWON, the World Bank developed a proxy indicator, *adjusted net savings*. The relationship between change in wealth per capita and adjusted net savings is discussed in chapter 2.)

The change in wealth per capita combines all assets into a single indicator by applying a common unit of measurement: monetary value. This implies a high degree of substitutability among different forms of capital (weak sustainability) and does not convey the very real limits to substitutability, impending thresholds for natural capital, or potential irreversibilities and catastrophic events. Given the poor state of the world's ecosystems, which can threaten the fundamentals of economies, these are serious concerns. The CWON makes use of underlying biophysical data, such as forest extent, to construct natural capital accounts that can be used to inform sustainability analysis.

In addition, economic sustainability is not the same as human well-being. Wealth, like gross domestic product (GDP), is intended to represent material well-being, not broader human well-being. Although per capita wealth may be similar for different countries, the well-being of their citizens may be quite different because of such factors as institutions, governance, and social capital that influence but cannot be directly incorporated into economic values. Such concerns gave rise to the widely embraced "beyond GDP" movement that has led to new approaches in measuring well-being, broadly defined.

Many of the new measurement approaches have greatly improved the ability to create a more comprehensive measure of national wealth, especially for natural capital. Wealth and GDP are essential companions. When properly understood and combined, they provide the financial tools for managing human economies, although they are not sufficient on their own for addressing sustainability and human well-being—that requires additional indicators of critical natural capital and social capital.

Capital for the 21st Century (World Bank 2006), was a proof of concept that demonstrated that wealth accounts could be constructed for a large number of countries. The second edition, *The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium* (World Bank 2011), provided the first time series of wealth accounts for 140 countries over 10 years. This allowed readers to examine the dynamic relationship between development and wealth. The most recent edition, *The Changing Wealth of Nations 2018: Building a Sustainable Future* (Lange, Wodon, and Carey 2018), included, for the first time, an explicit measure of countries' human capital. These editions of the CWON developed the argument for a new metric of sustainability for economic development, c*hange in wealth per capita*, and demonstrated its usefulness in numerous applications.

Wealth and GDP are essential companions. When properly understood and combined, they provide the financial tools for managing human economies. But they are not sufficient on their own to fully address sustainability and human well-being. Additional indicators of critical natural capital and social capital are needed. This chapter returns to interpreting wealth in the broader context of sustainability after detailing the composition of comprehensive wealth accounts.

The full story told by GDP or wealth, however, lives in the underlying disaggregation of the accounts. People may be tempted to view an increase in the value of natural capital as a sign of improvement in the state of forests, land, and so forth or a fall in value as a sign of environmental decline. But values can change because of changes in quantity and/or price; scarcity or improved efficiency can drive up land value. Therefore, the underlying land accounts can better reflect the reality in countries. Understanding the meaning of a change in wealth requires looking at the underlying physical data used to compile the wealth accounts. This edition of the CWON makes those data much more accessible than they were in the past.

What Is Included in Comprehensive Wealth Accounts?

Wealth accounts are grounded in the concepts and framework of the System of National Accounts (SNA) 2008 (EC et al. 2009) and its extension for natural capital, the System of Environmental-Economic Accounting (SEEA) Central Framework (UN et al. 2014a) and SEEA Ecosystem Accounting (UN 2021; UN et al. 2014b). Although there has been experimentation with human capital, it is not yet part of the SNA national balance sheet. CWON 2021 estimates wealth data for 146 countries from 1995 to 2018 in market exchange rates. (The data set can be accessed at http://www.worldbank.org/cwon/.) The wealth estimates are provided according to five asset classes (figure 1.1),[3] which are further explained in chapter 2:

1. *Produced capital and urban land*: machinery, buildings, equipment, intangible wealth such as intellectual property and mineral exploration, and residential and nonresidential urban land[4] (For the sake of brevity, the term *produced capital* is used to include produced capital and urban land.)
2. *Nonrenewable natural capital*: fossil fuels (oil, gas, and hard and soft coal) and minerals (10 categories)
3. *Renewable natural capital*: agricultural land (cropland and pastureland), forests (timber and ecosystem services), protected areas, mangroves, and marine fisheries
4. *Human capital*: the value of skills, experience, and effort by the working population over their lifetime disaggregated by gender and employment status (employed and self-employed)
5. *Net foreign assets*: the sum of a country's external assets and liabilities:[5] for example, foreign direct investment and reserve assets (For further explanation, see Lane and Milesi-Ferretti [2007, 2017].)

The key strength of including natural and human capital in national balance sheets is that it makes these assets visible to decision-makers, from civil society and private individuals to the private sector and policy makers, especially those dealing with the economy and finances. Providing transparent information about the value of natural capital puts it on the same economic footing as produced capital and supports the reality that, like any other asset, ecosystems need to be rewarded for their services, invested in, and managed well.

The strengths of adhering to the rigor of SNA-compatible balance sheets go hand in hand with the limitations of this approach. One limit is that some economic assets are more difficult to measure in market terms than others. CWON 2021 makes important strides toward rigorous valuation of blue natural capital, including fisheries and mangroves. It improves the coverage and rigor of valuation of several terrestrial ecosystems and agricultural land, as well as human capital. This makes the current edition of the CWON the most comprehensive source of wealth accounts available. The approaches have been explored and piloted so that additional asset classes can be included in future editions of the CWON: for example, climate regulatory services for the biosphere and renewable energy.

From Monitoring Economic Performance to Managing the Economy

All well-designed accounts, including the comprehensive wealth accounts, serve two purposes: (1) *score keeping* to indicate progress toward sustainability and (2) *management* to help understand how to improve the score if it heads in the wrong direction or maintain the score if it is on the right path. The initial motivation for the World Bank's wealth accounting program focused on the first goal, providing a forward-looking indicator of sustainability, the *change in wealth per capita*, and earlier editions of the CWON primarily addressed the measurement challenges to developing this indicator. In all the editions of the CWON, top-down estimates have increasingly been replaced by accounts built from the bottom up, using country-specific information. CWON 2021 continues to strengthen the measurement of wealth through expanded coverage and improved quality of all assets, notably, natural capital and human capital. It also increases country coverage.

The World Bank's extensive work to develop global wealth accounts has been necessary because, although the SNA includes guidelines for national balance sheets along with the income and production accounts that produce GDP, few countries regularly compile wealth accounts, even for produced capital and nonrenewable resources, let alone human and natural capital. Without reliable and consistent data, it is difficult to advance economists' analytical work. Growing recognition of the limitations of GDP has led to new emphasis on accounting for assets and on advances in expanding measurement to natural capital. The United Nations Statistical Commission's adoption of the SEEA in 2012 as an extension of the SNA was an important milestone (UN et al. 2014a, 2014b).

But implementation of the SEEA has been slow, and there is no statistical standard for the measurement of human capital (yet).

Change in wealth per capita has intuitive appeal among policy makers, but unless the measure is actionable, they may put it aside. Wealth accounts can be, and should be, put to broader use—if development is a process of building and managing a comprehensive portfolio of assets, then wealth accounts should be able to provide advice for policy questions: how much to save and invest, what mix of assets to invest in, and whether assets are managed efficiently or policy reforms are needed to do better. And how are various policies likely to affect assets and their long-term ability to provide benefits?

Wealth must be integrated into the diagnostics and toolkits used for macroeconomic and sectoral analysis and decision-making. This is a long-term agenda. The SNA (EC et al. 2009), on which the CWON is based, was originally designed for short-term policy concerns around national income and employment, with much less attention to assets, and much of macroeconomics has developed around the information provided by the SNA. Recent work by Dasgupta (2021), Hoekstra (2019), and the Organisation for Economic Co-operation and Development (OECD) (Stiglitz, Fitoussi, and Durand 2018), as well as work led by Diane Coyle of the Wealth Economy Project,[6] provides a clear explanation of why national accounts and macroeconomics have not fully integrated the asset side of national economies, especially natural capital.

With substantial progress in measurement, CWON 2021 now turns to using wealth accounts to meet policy needs. CWON 2021 begins that journey by applying the lens of wealth to analysis of important economic challenges. Key among those challenges is the management of assets under risk and uncertainty. Unlike GDP and national income accounts, which are backward looking, wealth accounts are essentially an attempt to peer into the future. By SNA and SEEA standards, the concept of asset value is the discounted flow of expected, future economic benefits to the owner. As fraught with uncertainty as the effort is, some prognostication about the future cannot be avoided. Households must make decisions about investments in education, health, marriage, jobs, child-rearing, and purchases of homes and cars. The private sector faces this challenge every day in its investment decisions, as do governments.

Climate change and, more recently, the COVID-19 pandemic loom as huge potential challenges to the productive value of all assets. These include physical risks to assets and transition risks from changes in policy, technology, working arrangements, and consumer preferences.[7] Sea level rise and increasingly intense storms may make vast areas of coastal settlements uninhabitable; extensive droughts and fires destroy assets, and changing weather patterns may greatly reduce the productivity of agricultural land in some places while increasing it in others; and fossil fuel deposits and the capital stocks (produced and human) that use them may lose their potential to generate income much earlier than expected. But the effects in a particular country and time are uncertain because the transition to a low-carbon economy could take many different paths that are yet to be chosen by different people.

In a recent report from the Bank for International Settlements (Bolton et al. 2020), some of the potential impacts of climate change are described as "green swans": events that (1) are rare and unexpected, hence outside regular expectations; (2) have the potential for extreme or wide-ranging impacts; and (3) can be explained only after the fact, not on the basis of past experience and probability distributions. The recent coronavirus pandemic illustrates that green swans are not limited to climate change effects.

What is the meaning of wealth accounts—the future value of assets—in such an uncertain world? To start to understand how such risks might affect wealth, CWON 2021 introduces a new component to the selected assets: estimates of value under scenarios of the potential impacts of climate change and, for human capital, the impact of the COVID-19 pandemic. CWON 2021 begins with baseline asset values, called *core accounts*, that are estimated under a fairly conservative approach that does not assume great change from the present.[8] This is not because the analysis assumes that the future will be like the past but because there is such great uncertainty and high variability among the global models of climate change and other events—thus, it is not useful to choose only one possible outcome. The core accounts provide a baseline that is not tied to any one projection of future impacts. This approach is consistent with the SNA, where a single figure for GDP is reported and a single figure for a country's net worth is reported, which can then be used for a wide range of scenario analyses.

When uncertainty is deep, meaning that the probability distribution of future critical external events and tipping points cannot be determined or agreed upon, it is helpful to navigate the plausible futures with a range of exploratory scenarios, or foresights, rather than a single rigid forecast of expected value. Against the CWON baseline based on highly simplified assumptions grounded in SNA and SEEA guidelines, asset values are simulated under a range of scenarios about the future, for comparison with the core accounts. This approach is not intended to argue that any one estimate is correct but rather to demonstrate how vulnerable various assets and national wealth may be under alternative and plausible versions of the future. The approach provides foresight, rather than forecast, into the future to inform prudent asset management decisions under uncertainty.

Role of Policies and Institutions in Creating Value for Natural Capital

Country policies, institutions, property rights, governance, and even what has been called social capital can influence how efficiently productive capital is used, the returns generated, and hence the value of an asset. These factors can vary over time within a country or across countries, even for an asset that is physically identical.

Prevailing market institutions and policies may distort the price that buyers and sellers face in markets, failing to inform users about the true value of an asset. Policy and market failures create a wedge between the true value and the price that is visible to economic agents. The resulting price incentive can result in overharvesting or degrading an asset. While all assets can be subject to these market failures, it is a particularly serious problem for natural capital, especially when ecosystem services are not priced at all and externalities—positive or negative impacts not felt by the parties to a transaction—exist, such as the damages from carbon emissions or the benefits of renewable energy that reduces carbon emissions. Many ecosystems and the services that underpin and embed all other assets go systematically undervalued, and, as a result, ecosystems are mismanaged.

Furthermore, many natural systems, such as the atmosphere or open oceans, do not have "owners" and property rights assigned. Therefore, their governance is subject to the "tragedy of the commons" (Hardin 1968; Ostrom 1990). Many negative impacts on markets are visible only long after the critical ecosystems degrade, making them subject to the "tragedy of the horizon" as well (Carney 2015). These three market failures explain in economic terms why countries need adequate policy intervention to evoke value from nature and manage natural capital sustainably.

The good news is that, over the past several decades, this problem has been recognized and tools for more accurately pricing or otherwise rewarding ecosystem services have been developed. Some of the chapters in this volume apply information from the wealth accounts for policy analysis to help countries unleash value creation from renewable natural capital, such as fisheries and renewable energy, and manage the risks of excessive dependence on nonrenewable natural capital.

Roadmap for the Report

This report is divided into four parts. The first part reviews overall trends in wealth accounts over the past 24 years, focusing on how those trends may have changed since CWON 2018, and introduces wealth in purchasing power parities (PPPs). The second part describes the new work on renewable natural capital and human capital, focusing on trends in human capital and potential impacts of the COVID-19 pandemic as well as on air pollution. The third part discusses several applications of wealth accounting to policy. The fourth part discusses new developments to increase the coverage of wealth accounts for important assets that are currently missing.

Part I. Global, Regional, and Country Trends in Wealth, 1995–2018

The main goal of the report's first part is to broaden the measures used to assess economic progress by providing forward-looking indicators based on wealth, which is defined to encompass most productive assets. Chapter 2 begins with a detailed explanation of wealth accounting. Chapter 3 provides the big picture, showing broad trends in wealth at the global level over the past two decades and progress toward convergence among income groups. The chapter explores how the volume and composition of wealth have changed over time for different income groups and takes a closer look at wealth in low- and middle-income countries by geographic region.

The chapter explores in depth the reasons some countries have failed to significantly increase their per capita wealth over the past 24 years.

Chapter 4 looks more closely at the unequal distribution of wealth across countries, using PPPs instead of market exchange rates. Market exchange rates have limitations for understanding how material well-being varies across countries, because one US dollar can purchase different amounts of goods and services across countries. To adjust for this and provide a better understanding of comparative material well-being across countries, the International Comparison Program estimates PPPs for broad categories of goods and services, which the chapter applies to the wealth accounts. In 2018, the OECD's market exchange rate–based total wealth per capita was 58 times greater than the low-income average—a vast difference. Although it is still large, the gap narrows to 21 times when valued in PPPs.

Part II. Measuring Comprehensive Wealth: New Work on Natural Capital and Human Capital

The second part provides a more detailed discussion of trends in specific assets, including assessment of risk under different climate change scenarios. The information presented here leads to a deeper understanding of comprehensive wealth and provides a resource that can be used for many kinds of analysis. Part II begins with two chapters on renewable natural capital and then addresses human capital.

Chapter 5 reviews land accounts for agriculture, forests, and protected areas. The chapter reports on new work on agricultural land and forests. Through spatially explicit modeling, estimates of cropland value are provided based on three regional and country factors that affect yields: technological improvements, climate change, and land degradation. New work on forest ecosystem services, based on the SEEA Experimental Ecosystem Accounts, builds wealth accounts from spatially disaggregated data for three ecosystem services: water services, recreation services, and nonwood forest products. It is now possible to analyze how the provision of each of these services has changed over time, with changes in the extent and condition of forest land.

Chapter 6 fills one of the CWON's major data gaps: blue natural capital. Blue natural capital in CWON 2021 includes accounts for mangroves and marine fisheries; future work will include additional components such as offshore renewable energy. Mangroves are valued for their coastal protection service.[9] The fisheries accounts build on work introduced in CWON 2018, examining the influence of subsidies on fisheries' asset value and the potential impacts of climate change on asset value under alternative scenarios.

CWON 2018 introduced human capital accounts for the first time, measured as the expected value of future lifetime earnings (Lange, Wodon, and Carey 2018).[10] It showed that the accumulation of human capital has been a key factor in economic growth, sustainable development, and poverty reduction. Chapter 7 examines trends in human capital accounts by country and gender and includes a discussion of human capital in the informal sector. Preliminary estimates of the effects of the COVID-19 pandemic on human capital are based on the likely impact of the massive economic downturn on wage growth rates, which would permanently lower the trajectory of wage growth and future income. CWON 2021 covers only the period to 2018; the long-term impacts of COVID-19 have not yet been felt or fully understood. These accounts stand as a pre-COVID-19 benchmark for the next edition of the CWON.

Chapter 8 estimates the impact of air pollution exposure on human capital through premature deaths, using data from the Institute for Health Metrics and Evaluation. As a leading health risk, air pollution represents a loss of human capital and national wealth. This annual cost is captured implicitly in the annual survival rates used to calculate human capital. The chapter makes that portion of mortality explicit to measure the loss of human capital resulting from exposure to air pollution from 1995 to 2018. Premature deaths declined over the period but still remain high in some countries.

Part III. Applying Wealth Accounts for Policy Analysis

An important benefit of comprehensive wealth accounts is for guiding public policy. By shedding light on different components of wealth, as well as their evolution over time, policy makers can evaluate the sustainability of economic growth and understand how to manage assets and build wealth for the future.

Nonrenewable natural capital is discussed in chapter 9. The chapter presents trends in nonrenewables such as oil, gas, and mineral wealth. For the first time in the CWON, new decomposition analysis allows decomposing changes in wealth by their contributing factors. For example, where nonrenewable wealth has decreased, the analysis reveals the extent to which this was driven by physical depletion, lower prices, higher costs, or other factors. The chapter also explores the danger of dependence on nonrenewable natural capital for development. In earlier times, such dependence was a successful strategy for increasing wealth and national income in some countries, and nonrenewable wealth grew fairly consistently from 1995 to 2014. However, global prices for fossil fuels have declined precipitously since 2014 and have not fully recovered. The broad economic downturn resulting from the COVID-19 pandemic and the potential for declining demand for fossil fuels in the future puts at risk the development of many countries that are heavily dependent on nonrenewables.

Chapter 10 explores the potential implications of climate and trade policy scenarios and the global low-carbon transition for national subsoil energy wealth. Many countries are rich in and dependent on fossil fuel wealth. However, international efforts to meet the goals of the Paris Agreement may significantly reduce the economic benefits that these countries expect from their fossil fuel assets. A transition away from fossil fuel consumption—whether policy or technology induced—may have serious implications for certain countries. The value of their subsoil energy wealth may decline precipitously in the coming decades. The risk to individual countries and fuels varies depending on when and how the low-carbon transition unveils. The chapter provides simulations of how different scenarios of cooperative and unilateral climate policies and broader carbon adjustments might affect national subsoil energy wealth.

Chapter 11 applies the CWON accounts to macroeconomic and fiscal management questions. The chapter illustrates how conventional measures of fiscal sustainability overlook important wealth considerations, such as the depletion and degradation of natural capital. If it is not offset by accumulation of other assets, economic growth driven by resource depletion is fundamentally unsustainable. The chapter provides a guide for policy makers to make better use of wealth accounts.

Chapter 12 explores the linkages between nonrenewable natural capital and human capital. Nonrenewable natural capital can create distortions in the economy, such as the Dutch disease. This in turn can impact the accumulation and distribution of human capital in the economy. A better understanding of these linkages can help policy makers to mitigate the distortionary effects and ensure greater wealth sustainability.

Chapter 13 explores the usefulness of comprehensive wealth accounts for finance and the financial sector. Growing interest in environmental, social, and governance aspects of financing, as well as innovative financial instruments such as green bonds, has increased attention on country performance in a wider range of measures beyond GDP. The chapter explores the value of comprehensive wealth accounts and, in particular, measures around the sustainable management of renewable natural capital that investors and the financial sector can use.

Part IV. New Developments in Measuring Wealth

The fourth part reports on two new developments, which were poorly measured in the past or not measured at all, and the prospects for including them in future work on wealth accounts: renewable energy and social capital.

Chapter 14 proposes the first experimental effort to develop renewable energy asset values for the CWON. It develops an SNA-consistent methodology that includes hydroelectricity, solar, and wind electricity assets in the national balance sheets. The chapter demonstrates the proof of this concept by estimating values for the renewable energy assets of 15 countries. The results show that leaving renewable energy assets off national balance sheets misses a great deal of wealth. The chapter also identifies methodological issues to address before considering inclusion of renewable energy assets in the core CWON natural capital accounts. The trends in the values of renewable energy assets are compared with the trends in the values of fossil fuel wealth for selected countries. Lastly, the chapter presents simulations of the future values of renewable energy assets under alternative climate and energy policies.

Chapter 15 discusses the concept of social capital and its impact on nations' wealth and prosperity. It provides an overview of conceptual approaches to social capital and its definitions. It also discusses measurement challenges and applications in policy making. The chapter provides recommendations for the role of social capital in the national accounting framework and future editions of the CWON.

Summing Up and Future Research

The goal of CWON 2021 is to advance the important tasks of measuring wealth to assess sustainability, applying wealth accounts to policy, and addressing some of the most urgent global issues. With 24 years of wealth accounts covering 146 countries and 22 classes of natural capital assets, human capital, and produced capital, CWON 2021 provides a great source of information that the World Bank hopes will be widely used in the coming years. To promote this broad analytical endeavor, an online platform has been developed that will make the wealth accounts and much of the underlying data publicly available.

This report contains model simulations of the future value of selected assets, complementing the accounting approach of the CWON core accounts. The goal is not to predict future asset values but to inform decision-making under uncertainty. Uncertainty is represented by the set of exploratory scenarios built from several plausible combinations of potential external impacts and policy choices. This approach can be interpreted as the simplest way to represent deep uncertainty, where the probability of events affecting future wealth is unknowable or cannot be agreed on by stakeholders. Constructing a wide range of future scenarios provides an opportunity to identify policy and investment choices that make wealth portfolios resilient or vulnerable under a range of plausible but unpredictable external shocks (green swan events) as well as endogenous choices that may be made by future decision-makers.

The report demonstrates how comprehensive wealth accounts provide a valuable tool for economic analysis and diagnostic exercises. By tracing the distribution and evolution of different categories of wealth in a country, economists can better understand the sustainability of growth and the structural changes in the economy. Chapter 11 provides examples and guidance to World Bank country economists on how they might use the wealth accounts for Systematic Country Diagnostic reports and Country Economic Memorandum exercises and provides a blueprint for how others might use the wealth accounts as well. Furthermore, the chapter examines measures from the wealth accounts that can supplement traditional macroeconomic indicators for understanding the sustainability of economic development and public finances.

The wealth accounting approach allows for a better appreciation of the components of wealth, that is, a better reflection of natural capital's contributions to wealth, which GDP is too narrow to demonstrate. Individual components of the wealth accounting approach are already widely used. For example, information about mineral accounts from the previous editions of the CWON has been used in more than 100 published articles analyzing a wide range of topics, particularly on natural capital and economic growth.[11]

Much work remains to be done, however. On the measurement side, the chapters in part IV show where it is feasible to expand coverage to meet the goal of *comprehensive* wealth accounts: renewable energy and social capital as well as biodiversity and carbon accounts. These advances are somewhat different in nature. Adding renewable energy and water to the core CWON accounts can be done, depending on data availability. This report provides a proof of concept that renewable energy can be part of the national balance sheets and develops experimental renewable energy accounts for a sample of countries. Although there are a lot of data for carbon, there is not yet agreement about how to account for carbon in the SEEA; the complexities of this issue are discussed in annex 1A, at the end of this chapter. Biodiversity and social capital are what Dasgupta (2021) refers to as enabling characteristics of assets, a quality that gives value to other assets. Social capital will not be part of the core monetary accounts, but it will provide an essential, complementary indicator to the change in wealth per capita to assess development. Further analytical work may illuminate how social capital adds value.

As social capital is brought into the broad sustainability framework to complement monetary measures of sustainability, there is also a need to address biodiversity and *critical* natural capital: renewable natural capital where losses and degradation have brought ecosystems to potentially irreversible thresholds that may precipitate catastrophic events. As noted in earlier editions of the CWON, changes in wealth per capita provide only a measure of "weak" sustainability that implicitly assumes a high degree of substitutability among different kinds of assets. The emergence of multiple global crises, such as biodiversity loss, climate change, or ocean pollution, is a strong wake-up call about the limits to replacing several critical ecosystem services with human-made substitutes. Within countries, the mix of wealth can make a difference for development prospects and exposure to various risks, and the interaction between and among various components of wealth may be crucial.[12]

There have been great improvements in measuring ecosystem conditions and services, based on rapid advances in remote sensing and the ability to interpret such data through integrated assessment models. But identifying and quantifying potential tipping points in the context of national wealth accounts still remains highly uncertain. To date, the CWON accounts have reported measures of wealth at the national and annual levels. However, improvements in data, including via remote sensing methods, have opened possibilities for greater spatial and temporal measurement of wealth. Future editions of the CWON may explore increased spatial and temporal granularity to meet the needs of different stakeholders and improve the targeting of policy interventions for sustainable wealth management.

There are limitations in the estimates of produced capital and human capital that may be addressed in future editions. It would be useful to disaggregate produced capital by public and private sector, and the International Monetary Fund has done some estimates that could be incorporated into future editions of the CWON (IMF 2019). Produced capital is measured as the sum of investment minus normal depreciation. The lack of adjustment of produced capital stocks for losses caused by catastrophic events was noted earlier, and efforts to incorporate them would make the accounts more useful. A recent study by the UK Office for National Statistics finds that the normal depreciation rates that have been in use for many years do not reflect current depreciation and suggests revision (ONS 2019). Others have called for a review of what should be considered normal depreciation rates, in light of the impact of climate change, the "new normal."

Obsolescence of capital is another issue that is not addressed in global databases on produced capital. The shift to home-based work in response to the COVID-19 pandemic is an extreme example of rapid obsolescence. This shift resulted in the obsolescence of many business assets (offices and equipment, buildings, and transportation capital), partly offset by an increase in household office durables and private sector expansion of communications and information technology–related capital goods to support home-based work. These changes will be difficult to quantify in the near future.

Human capital accounts are limited to what is defined as economically productive activity in the SNA. It captures the contributions of health and education but excludes much of the unpaid work done in households. Household work to produce goods, such as growing food for own use, is included in the SNA, but the provision of services such as childcare, food preparation, and other services is not. The implications of the transfer of human capital through permanent or temporary migration is another area of great concern and not directly measured by the core accounts.

Several broader policy issues remain for the next edition of the CWON. Although the current edition of the CWON considers the impacts of climate change on asset value, it does not include carbon sequestration as an asset. Discussion of this in CWON 2011 identified challenges associated with including carbon sequestration in the core accounts, and this will be addressed in the next edition of the CWON.

Including the asset values of natural capital acting as carbon sinks or subtracting from national wealth the cost of carbon emissions presents challenges for the SNA and SEEA approach at present. This is due to the absence of widely applied carbon prices, as well as the lack of national and international frameworks for valuing carbon storage. Similarly, much of the value of biodiversity and critical natural capital is not amenable to a wealth accounting approach at this time, because of the absence of clear market valuation for such vital natural phenomena. In this absence, despite the importance of these issues, they cannot readily be put on the balance sheet, for example as an income-generating asset. It is hoped that policy progress on biodiversity, climate change, and valuing nature, at the national and international levels, will help advance these topics, and that in the future it will be feasible to measure their contributions to national wealth.

A global push for greater inclusivity to remedy the extreme inequality in the distribution of income and wealth is a major issue. Data are available for better understanding the distribution of human capital between genders, but not for other assets. While the CWON is able to quantify the distribution of wealth among countries, the data are not available for extending that to the distribution and inequality within nations.

An intriguing issue for the CWON is the aftermath of the COVID-19 pandemic, which has left countries with unprecedented levels of debt liabilities. This has led to a call for greater transparency and a greater focus on national debt and its long-term economic impacts. This may be an avenue for broadening interest in comprehensive wealth, balancing government debt against all government assets, including natural capital, as well as the nation's assets and liabilities.

To conclude, this edition of the CWON describes some of the main findings emerging from the new wealth accounts. The analysis and the abundance of data—which will become available online—should generate new questions about development, the dynamics of how countries accumulate wealth, and how to promote efficient and equitable use of wealth. Sustainability into the 21st century will depend not only on the assets base but also on the strength of institutions and governance and the integrity of natural capital. This new CWON sets the stage for addressing these issues in an integrated manner. The hope is that it will help generate new research and insights for policy.

Annex 1A: Treatment of Carbon Accounting in the SEEA Ecosystem Accounts

Global Climate Regulation Service in the System of Environmental-Economic Accounting Ecosystem Accounts

The System of Environmental-Economic Accounting (SEEA) Ecosystem Accounting Accounts (UN 2021, chap. 6.4.3) recommends considering global climate regulation services (in the case of carbon) as a single service consisting of two components: a carbon retention component and a carbon sequestration component. This distinction reflects the role of ecosystems in terms of storing carbon over a long time, thereby avoiding its release, as well as removing carbon from the atmosphere. The SEEA Ecosystem Accounts provide the general approach; more specific guidelines on biophysical modeling and valuation of climate regulation services are expected to be released later in 2021 or in 2022.

One Service, Two Components

Measuring the carbon retention component consists of (1) estimating carbon stocks of relevant carbon pools at the beginning of the accounting period, (2) valuing these stocks using a suitable carbon price, and (3) deriving an annual service flow by multiplying this value by a suitable rate of return (to create a perpetual annuity). The scope of measurement of a carbon retention service is in principle limited to terrestrial ecosystem assets (excluding geocarbon stored in subsoil assets such as oil and gas) and restricted to what the Intergovernmental Panel on Climate Change calls *long-lived biomass* (excluding carbon stored in aboveground biomass in cropland). The carbon sequestration component is measured using the net ecosystem carbon balance, taking into account all changes in carbon stocks (for example, changes resulting from respiration, timber harvest, or forest fires) and can be valued by multiplying these changes by a suitable carbon price.

The use of two components recognizes that countries face very different circumstances in terms of the dynamics of changes in carbon stocks, with some experiencing slow changes and others undergoing large changes resulting from changes in land use or as a result of fires. These differences are reflected in the range of policy instruments that exist. Some focus on reducing and/or avoiding emissions: for example, reducing emissions from deforestation and forest degradation in developing countries and avoiding emissions through conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries (REDD+). Others focus on stimulating carbon uptake (for example, mechanisms developed under article 6 of the Paris Agreement).

In contexts where carbon stocks are declining, for example, because of timber harvesting or land-use changes, the retention component ensures that the accounts reflect carbon losses in terms of a decrease in retention services provided. In turn, this may be reflected in a measure of ecosystem degradation in the monetary ecosystem asset account. Ecosystems with high carbon stocks (for example, tropical rain forests) provide relatively high retention values (although often they have low sequestration, as they are in equilibrium), signaling that they are worth preserving.

Pricing Carbon

The approach allows the use of different prices for the two components of the service. In the case of carbon retention, it is recommended to apply a social cost of carbon (SCC), as this aligns with the framing of avoided damages. When choosing a SCC, it is important that it is derived from models that are consistent with the exchange value concept that is the basis of the System of National Accounts,[13] that is, limited to assessment of the effects on measures of output. For the carbon sequestration component, the recommendation is to use suitable carbon market prices where they are available.

Examples

NSO India (2021) estimated the carbon retention provided by India's forests for two consecutive periods (2015–16 and 2017–18). It first estimated the total carbon stock consisting of aboveground biomass, belowground biomass, dead wood, and litter, as well as soil organic carbon, using data from the Forest Survey of India. This physical stock estimate was valued using a country-specific social cost of carbon. Finally, the avoided damage value was turned into an annuity by using a 3 percent rate of return. It was found that the annual retention service provided to the world was equivalent to 2–3 percent of India's gross domestic product, and more than twice as large as the gross value added of its forestry sector. The state-wise estimates of the value of carbon retention are presented in table 1A.1.

Turpie et al. (2021) value and map carbon retention in KwaZulu-Natal province, in South Africa, using an SCC approach. The study contains a sensitivity analysis of the portion of damages that would impact the province, as well as the value in case of global damages. ONS (2019) values carbon sequestration using the United Kingdom's prescribed carbon price.

TABLE 1A.1 State-wise Value of Forest Carbon Retention Services in India, 2017–18

State/union territory	Carbon retention service (Rs/ha/year)
Andhra Pradesh	8,291
Assam	21,197
Bihar	3,610
Chhattisgarh	21,863
Delhi	5,130
Goa	42,125
Gujarat	3,363
Haryana	1,457
Himachal Pradesh	27,898
Jharkhand	13,744
Karnataka	12,315
Kerala	33,735
Madhya Pradesh	11,755
Maharashtra	8,811
Manipur	49,266
Meghalaya	49,658
Mizoram	45,706
Nagaland	50,311
Odisha	17,087
Punjab	1,631
Rajasthan	1,949
Sikkim	49,594
Tamil Nadu	10,258
Telangana	8,338
Tripura	44,640
Uttar Pradesh	2,955
Uttarakhand	42,683
West Bengal	10,243
Andaman and Nicobar Islands[a]	84,060
Chandigarh[a]	10,404
Dadra and Nagar Haveli[a]	22,563
Daman and Diu[a]	8,428
Lakshadweep[a]	48,416
Puducherry[a]	5,062
Other territories (average)	44,036

Sources: MoSPI 2020; NSO India 2021.
Note: ha = hectare; Rs = Indian rupees.
a. Union territory.

Notes

1. The calculation of net domestic product or net national income deducts depreciation of fixed capital, but GDP does not.
2. The terms *wealth* and *balance sheet* are used interchangeably. And note that publicly traded extractive firms are increasingly required by international stock exchanges to include the estimated value of their natural resources and reserves, the natural capital component of their balance sheet.
3. Previous editions of the CWON classified assets into four classes, but here natural capital is divided into renewables and nonrenewables because they differ greatly in terms of management for development.
4. Urban land is a nonproduced asset in the SNA, but here it is separated from other nonproduced assets (natural capital) to focus on the other forms of natural capital.
5. Domestic financial assets do not add to national wealth because "assets plus liabilities" sum to zero. It would be quite useful to have such information, but the data are not readily available for many countries.
6. The Wealth Economy Project is located at the Bennett Institute for Public Policy, University of Cambridge, UK, https://www.bennettinstitute.cam.ac.uk/research/research-projects/wealth-economy-social-and-natural-capital.
7. In the rest of the text, climate change risks are meant to cover physical risks and policy transition risks unless otherwise noted.
8. This is the approach generally recommended by statisticians for the SNA and SEEA when the factors determining future values are not known.
9. Mangrove timber and nontimber products, which are typically much smaller in value than coastal protection services, are already included under the forest accounts.
10. Other, nonmonetary approaches to human capital are discussed in chapter 7.
11. G. Davis, Colorado School of Mines, personal communication, January 15, 2021.
12. Johnson et al. (2021) provide estimates of country vulnerability to ecosystem collapse.
13. Exchange values are the values at which goods, services, labor, or assets are exchanged or could be exchanged for cash (SNA 2008, para. 3.118).

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2

How Wealth Is Measured: Basic Approach and New Developments

Glenn-Marie Lange and Esther Naikal

Main Messages

- Wealth accounts are built on the concepts and methods laid out in the System of National Accounts (SNA) and the System of Environmental-Economic Accounting (SEEA).
- Wealth accounts measure the financial value of the stock of assets available for production and consumption; they do not measure broad human welfare.
- Wealth accounts provide an indicator of sustainability, the change in wealth per capita, which is necessary but not sufficient on its own to assess sustainability. Complementary indicators for social capital and critical natural capital are needed to cover all the components of sustainability: economic, social, and environmental.

How Wealth Is Measured

Like gross domestic product (GDP), wealth accounts are intended to estimate the financial worth of assets, which is critical for economic management, but not broad human well-being. Also like GDP, which is often criticized for not representing well-being, wealth accounts may be expected to provide more than intended. This chapter takes a closer look at how wealth is measured, the factors that contribute to a change in wealth per capita over time, and some of the issues that are critical for a correct interpretation of the wealth accounts. The purpose is to make clear what wealth includes and what it does not, how it can be used, and inappropriate uses of wealth.

Wealth accounts are grounded in the framework of the SNA 2008 (EC et al. 2009). The SNA measure of wealth is much narrower than what is presented here because the SNA asset boundary includes only produced assets, natural resource assets, and net foreign assets. The SEEA Central Framework (UN et al. 2014a) and SEEA Ecosystem Accounting (UN 2021; UN et al. 2014b) expand the SNA to develop the methodology for natural capital accounts. Although there has been experimentation with human capital, it is not yet part of the SNA national balance sheet. This edition of *The Changing Wealth of Nations* (CWON) estimates wealth data for 146 countries from 1995 to 2018.[1] The wealth estimates are provided according to five asset classes (see figure 1.1, in chapter 1):[2] produced capital and urban land, nonrenewable natural capital, renewable natural capital, human capital, and net foreign assets.

For some assets, such as produced capital and net foreign assets, the asset values used in this report are directly available from other sources. The values of other assets are estimated using data collected from a wide range of global sources, as described in appendix A. Given the need to harmonize data across countries, the wealth accounts for any country are unlikely to be as accurate as the accounts that the country might construct itself using its own, more accurate and comprehensive data sources. Here, the value addition lies in the provision of comparable measures of wealth for many countries, with countries included when data for the core set of assets are available or can be reasonably estimated. That said, chapter 10 explores the potential impacts of policies to support a low-carbon energy transition on national wealth. This effort sits at the intersection of accounting and analysis; it is useful, not only for the specific results it generates, but also as a demonstration of how to undertake a more detailed assessment of wealth and how it may change.

The construction of the wealth accounts is guided by the concepts and methods of the SNA. Although values for produced capital and net foreign assets are generally derived from widely used methods based on observed transactions for these assets, the value of many natural capital assets and human capital must be estimated. The approach to asset valuation is based on the concept that the value of an asset should equal the discounted stream of expected (net) earnings (for example, resource rents or wages) that it earns over its lifetime. This in turn depends on the ability to measure the earnings stream. For those features of the economy that do not generate explicit rents or income—such as with forest ecosystem services such as watershed protection—this must be derived, or it may fall outside the current SNA boundaries, so that it is not possible to place a monetary value on it. Such is the case with carbon dioxide emissions, natural carbon sinks, or the important roles played by biodiversity, critical natural capital, or clean air.

For natural capital, the practical recommendations of the SEEA are used as a guide (UN 2021; UN et al. 2014a, 2014b). The SEEA is an extension of the SNA, using consistent concepts and structure and providing the basis for the estimates of the value of natural capital. Several key simplifying assumptions are made for valuing natural capital in the CWON's core accounts. Although these assumptions are often replaced in estimates undertaken by countries themselves, where access to country-specific data may be available, they are necessary for a consistent data set for many countries over many years, when such information is lacking.

- *Future value of resource rent or ecosystem service*: the CWON core accounts typically assume that the rent remains constant in the future and do not include projections of future rents.
- *Lifetime of the asset*: if assets are being depleted (nonrenewables) or overharvested (renewables), the lifetime is given by the time to depletion, assuming constant levels of extraction. For renewable resources, a maximum lifetime of 100 years is used, drawing on guidance from the United Kingdom's natural capital accounting work (ONS 2020).
- *Discount rate*: a 4 percent discount rate is used for all assets. This rate was used in all the previous editions of the CWON and is further explained in World Bank (2006). Discounting is consistent with a financial approach to asset valuation, but it has been controversial and subject to a great deal of discussion. (See, for example, Stern 2006.)

No international statistical standard yet exists for human capital, but there has been a great deal of experimental work on this topic based on the Jorgenson-Fraumeni approach, including work by national statistical offices and the Organisation for Economic Co-operation and Development (OECD). To maintain consistency with the SNA, human capital estimates are restricted to earnings that are recorded in the SNA or that can be reasonably derived from data in a country's SNA. While the SNA includes unpaid household production of some goods, it excludes the production by households of services for final consumption within the household, such as family care, meal preparation, or home repairs. Women provide a disproportionate share of this unpaid work. Because these services are excluded from the SNA, the value of human capital to produce these services is also excluded from the human capital estimates provided in this report.

Comprehensive wealth is measured at market exchange rates in constant 2018 US dollars. Valuing wealth accounts using purchasing power parities (PPPs) provides a better understanding of the comparative material well-being derived from assets across countries, just as GDP can be measured using market exchange rates and PPPs. This important application is explored further in chapter 4.

How Wealth Changes over Time

Multiple factors contribute to changes, positive and negative, in wealth per capita, the indicator of sustainability (table 2.1). Although some of these factors may be obvious, others are less so because they may influence value in an indirect way. For example, reducing the level of

TABLE 2.1 Factors That Change Wealth over Time

Wealth per capita, beginning of period		
Factor	**Minus**	**Plus**
Produced capital	Normal depreciation Not included: catastrophic losses from natural disasters or civil conflicts, obsolescence	Investment in produced capital: buildings, structures, machinery, intellectual property
Nonrenewable natural capital	Extraction Other reductions in proven reserves and production volume Decrease in unit rent due to • Lower market price • Higher production costs Extended extraction path Not included: the impact of changes in future prices and policies, because these are unknown	Increase in proven reserves and production; increase in unit rent due to • Higher price • Lower production costs Accelerated extraction path Not included: the impact of changes in future prices and policies, because these are unknown
Renewable natural capital	Extraction greater than natural regeneration Degradation Decrease in unit rent due to • Lower market price • Higher production costs Not included: the impact of changes in future prices and policies, because these are unknown	Increase in harvestable extent, improved condition, increase in unit rent due to • Higher price and/or unit value • Lower production costs and/or improved efficiency Not included: the impact of changes in future prices and policies, because these are unknown
Human capital	Decline and/or aging of the labor force, declining wage rates, decline in education Changing wage growth trajectory due to economic shocks such as COVID-19 Not included: loss of human capital from missed schooling and health damages from COVID-19 Loss of human capital via migration	Growth of the labor force through growth of the domestic population, increased labor force participation, or migration (gain to one country, loss to another) Increasing wage rates; increasing education
Net foreign assets	Foreign liabilities	Foreign assets
Population change	Mortality Out-migration	Births Immigration
Wealth per capita, end of period		

Source: World Bank.

extraction of minerals extends the lifetime of a resource and pushes the delivery of rents further into the future, which reduces the value of the asset because future rents are discounted. In addition, there are often interaction effects among the factors. For example, the asset value of mangroves has increased over time although the extent of mangrove coverage has markedly declined. This has occurred because in many countries the unit value increased sufficiently to offset the decline in physical extent over the same period. The unit value is measured as damages prevented to produced capital, and produced capital has grown substantially, which caused the unit value of a hectare of mangroves to increase. Decomposition analysis is applied for the first time in CWON 2021 for better understanding the drivers of change; the analysis is discussed in chapter 9.

What Is Missing from the Wealth Accounts?

Losses due to catastrophic events, mainly natural disasters and civil conflicts, in produced capital and renewable natural capital such as cropland and forests are not included in the CWON core accounts. Such losses have become frequent and especially severe for low- and middle-income countries and are projected to increase under climate change. However, there is no global database of these losses that is consistent with SNA produced capital.[3] A few countries, such as Japan and the United States, include such losses in their national balance sheets when damages reach a specified threshold. But most countries do not even compile balance sheets and, if they do, do not include catastrophic events.[4]

Not all assets are yet included in the CWON 2021 database. Assets are included in the core database only when the necessary data (1) become available for a large number of countries (at least 100), (2) are updated regularly to provide a time series, and (3) are publicly available. Each edition of the CWON discusses selected assets that cannot yet be included in the core wealth accounts and provides a roadmap for their future inclusion. CWON 2018 proposed a way forward for marine fisheries, forest ecosystem services, and the impact of air pollution on human capital. All three of these are included in CWON 2021. Biodiversity remains a major omission, but there is controversy over whether it is a productive asset itself or what Dasgupta (2021) refers to as an enabling asset, something that supports the efficient functioning of other assets.

Similarly, not all countries are included in CWON 2021. For some countries, the missing data gap is too great to be filled reasonably. Many of the Small Island Developing States are absent for this reason, which is a particular challenge in introducing blue natural capital for marine assets.

Changes in CWON 2021 Core Accounts and Impact on Wealth Estimates

The World Bank has established the CWON as a regular publication that will be updated repeatedly. Major changes in the coverage or methodology for the core accounts are always applied backward to 1995 for a consistent time series, so the most recent edition is not strictly comparable to those published earlier. Although CWON 2021 takes the same overall approach to wealth accounts as previous editions, it differs from CWON 2018 in several important ways: (1) additional accounts for renewable natural capital, (2) improved methodology for natural capital (renewable and nonrenewable) and human capital, and (3) expanded country coverage. These changes and the impact on the wealth accounts are summarized in table 2.2 and table 2.3. The implications of these changes are discussed in chapter 3 and the relevant subject chapters.

Country coverage has increased from 141 countries to 146, but the distribution across regions and income groups remains fairly similar, although 17 countries changed their income classification. The reclassification of two large countries, Argentina and the Russian Federation, from

TABLE 2.2 Improvements in Data and Methodology for the Core Wealth Accounts

New accounts, updated data and methodology	Impact on new wealth accounts
Blue natural capital. New accounts for marine fisheries and mangroves (coastal protection service)	Increased value of renewable natural capital (and total wealth)
Agricultural land. New region- and country-specific crop yield growth rates: estimated at the grid-cell level, accounting for impacts of soil degradation and climate change	Global agricultural land value lower than previous estimates due to lower global average crop yield growth rate (0.5%) but varies by region
Forest timber. Broadened definition of forest area where timber is harvested	Increased value of forest timber wealth
Forest ecosystem services. Three forest ecosystem services for each country and year from values estimated at the grid-cell level	Increased per hectare value of forest ecosystem services
Minerals. New accounts using mine-level data on production costs for each mineral (S&P Global Market Intelligence); improved accuracy of rent and asset value estimates	Per new data source, much higher production costs and lower rents than earlier estimated, hence, lower mineral wealth
Human capital. Region- and income group–specific wage growth rates replacing previous estimate of 2.46% used for all countries. New rates are higher in low- and middle-income countries in East Asia and Pacific, lower in high-income countries and low-income countries in Africa New data for the Middle East and North Africa's Gulf Cooperation Council countries based on access to survey data for Saudi Arabia	Higher (lower) human capital in countries with higher (lower) wage rate growth than 2.46%

Source: World Bank.

TABLE 2.3 Country and Income Group Coverage: CWON 2018 versus CWON 2021

	Number of countries	
Income group	**CWON 2018**	**CWON 2021**
Low-income	24	24
Lower-middle-income	37	36
Upper-middle-income	36	42
High-income: non-OECD	15	12
High-income: OECD	29	32
Global	**141**	**146**

Source: World Bank.
Note: OECD = Organisation for Economic Co-operation and Development.

high-income non-OECD in 2014 to upper-middle-income in 2018, reduces the already small number of countries in the high-income non-OECD group.

New countries added in CWON 2021:

- Benin
- The Czech Republic
- The Islamic Republic of Iran
- Lesotho
- Trinidad and Tobago

Countries that moved up in income groups from 2014 to 2018:

- *Low- to lower-middle:* Cambodia, the Comoros, and Zimbabwe
- *Lower-middle to upper-middle*: Armenia, Georgia, Guatemala, Guyana, and Sri Lanka
- *Upper-middle to high-income non-OECD*: Panama
- *Joined the OECD*: Latvia and Lithuania

Countries that moved down in income groups from 2014 to 2018:

- *Lower-middle to low-:* Tajikistan and the Republic of Yemen
- *Upper-middle to lower-middle*: Mongolia and Tunisia
- *High-income non-OECD to upper-middle*: Argentina and Russia

Wealth, Adjusted Net Savings, and Sustainability

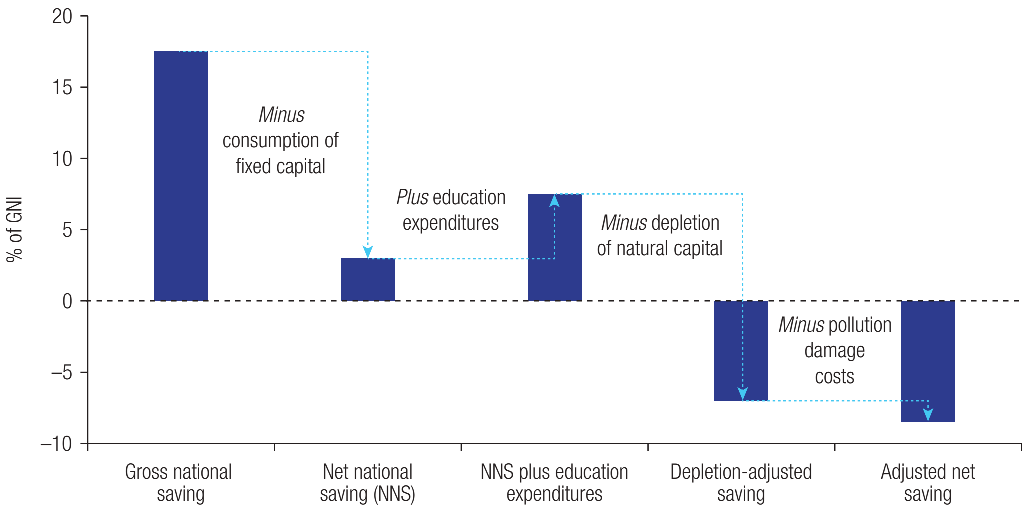
Income measures such as GDP can be understood as the annual production generated by a country's use of its asset base. Said differently, income can be understood as the annual return that a country derives from its wealth. Therefore, the key to increasing economic well-being in the future lies in building national wealth. This, in turn, requires savings to finance this investment, as well as good institutions and governance to make productive use of assets. From a wealth accounting perspective, development can be viewed as a challenge of portfolio management, with countries deciding how much to save or consume each year, what assets to invest in, and how to make the most efficient use of their assets.

In the 1990s, the World Bank introduced the concepts of wealth underpinning national income, and long-term prosperity as dependent on wealth, but it had no widely reported data to monitor wealth at that time. To fill this gap, Hamilton and Clemens (1999) developed an indicator, adjusted net savings (ANS), also known as genuine savings, as a proxy for the change in wealth (but not per capita wealth). In accounting conventions, saving equals investment, but by the same conventions, change in wealth is more than investment, as shown in table 2.1. In the early days of the work on wealth, the ability to compile comprehensive wealth accounts was limited, so a proxy indicator that could be compiled quickly was a great advance. ANS also had the advantage of being easy to understand. However, ANS provides only part of the picture of wealth and how it is changing.

ANS is measured as gross national saving minus depreciation of produced capital, depletion of subsoil assets and timber resources, and air pollution damages to human health, plus a credit for expenditures on education (see figure 2.1). The rule for interpreting ANS is simple: if ANS as a percentage of gross national income is negative, it indicates that the country is consuming more than it is saving, which will undermine long-term sustainability; if ANS is positive, then it is adding to wealth and future economic well-being.

For countries with growing populations or aspirations to higher standards of living, it is not sufficient to maintain wealth; per capita wealth

FIGURE 2.1 Procedure for Estimating Adjusted Net Saving



Source: World Bank.
Note: GNI = gross national income.

must be growing, or at least not declining. Comprehensive wealth accounts show the value of various assets at a point in time and can be used to monitor whether per capita wealth is maintained or increased over time. This is a simple criterion for sustainable, long-term growth. ANS provides a complementary indicator to help in understanding the dynamics that drive the changes in wealth from one period to the next, by capturing some of the important policy-induced dynamics.

Measured annually, ANS provides policy makers immediate feedback about the direction of the economy and possible actions they may need to take to ensure long-term growth. By breaking down its components, it is easy to discuss policy interventions that could improve a nation's ANS, such as increasing the level of gross saving; improving the quality and maintenance of built capital to achieve a longer lifetime and improved resilience to reduce the depreciation of fixed capital; increasing investment in education and innovation to increase human capital; optimizing the use of natural capital (sustainable use of renewables and efficient extraction of nonrenewables); or improving air quality to reduce pollution damage costs.

Although ANS is a very useful concept, it can differ significantly from changes in wealth, as explained in box 2.1. Many factors affecting wealth are not included in ANS because of SNA conventions for saving and investment. This means that it is possible to observe negative (or positive) ANS and an increase (decrease) in wealth, even if this is typically not the case for most countries. Much of the difference between ANS and changes in wealth results from factors that are omitted from the ANS (such as agricultural land and changes in human capital) or treated as exogenous in the SNA and SEEA (such as new discoveries of minerals or increased

BOX 2.1 Savings and Changes in Wealth

In economic theory, investment net of depreciation and depletion equals the change in wealth. However, because of practical data limitations in measuring adjusted net savings (ANS), as well as the System of National Accounts (SNA) accounting definitions for savings and investment, this is not the case for the Changing Wealth of Nations wealth accounts. There may sometimes be a significant gap between ANS and the change in wealth.

Several factors that affect national wealth are currently omitted from ANS because of a lack of data (a weakness that could be corrected in the future). These factors include (1) changes in the extent and value of agricultural land, as well as (2) changes in the present value of earnings for the labor force (the measure of human capital) that need not reflect investments through the public budget in education (the measure used for ANS).

In addition, some factors that affect national wealth are not included in savings and investment according to SNA conventions but are part of changes in wealth. These factors include the following:

- New discoveries of subsoil assets, which are only added to the balance sheet, not ANS
- Some capital gains or losses due to commodity price changes, which are included in wealth accounts when the gross domestic product deflator is used to value an asset in constant prices
- Changes in technology, world prices, and/or management that affect the productivity of an asset, or the volume of resources that are now economically feasible to exploit:
    - Improvements in extraction technology for energy and minerals that can make extraction of previously uneconomic resources feasible, increasing the volume of resources and adding to wealth (However, changes in technology may reduce the demand for other resources: for example, shale gas reducing the demand for and value of coal resources, or cheaper renewable energy sources that may reduce the demand for fossil fuel energy.)
    - Changes in world prices that increase the volume of resources, adding to wealth resources that previously were not profitable to exploit (a separate effect from capital gains/losses)
    - Agricultural land that increases in value if a farmer switches to higher-value crops or changes technology that results in higher yields or simply improves efficiency of management
- Policy changes affecting asset value: for example, trade policy, transport infrastructure, or environmental regulation impacting a country’s costs (Education, labor markets, and changes in the business environment may affect the opportunities for human capital and other assets. The effect would show up in higher returns and higher asset values in wealth accounts, but not in ANS.)
- Other exogenous impacts on assets such as civil unrest, natural disasters, or similar events

prudence in the government's fiscal and investment management). Thus, ANS may be observed to be negative although wealth may be increasing. More generally, squandering existing wealth, especially in the case of exhaustible resources that can finance future investment, can never be prudent. Negative ANS often suggests that opportunities to increase future economic well-being may be wasted for short-term gains, because it reflects a level of overall saving that is below the level of natural wealth being depleted.

Measuring Sustainability in the CWON

Given these considerations, the CWON preferred measure of sustainability is the change in total wealth per capita. This gives a fuller picture of how overall wealth is evolving, and it accounts for all asset classes and the change in population. Unsustainable management of the wealth portfolio—such as overfishing or consuming rather than investing resource rents—would lead to declining total wealth per capita if it were not offset by sufficient increases in the value of other assets in the portfolio.

GDP cannot illustrate the sustainability of prosperity, beyond changes in the annual flow. Therefore, if GDP is being increased by the depletion or degradation of assets, this would not be seen until much later, when such assets can no longer generate the same income flow. For example, a country might increase GDP in the short run via the destruction of forests for cheap agricultural land, or by overfishing its coastal waters. However, if left unchecked, such depletion of the underlying natural capital would eventually become a drag on GDP. Wealth accounting, and monitoring of the value of different assets, can help shed light on this much sooner than GDP can.

Total wealth per capita can help reveal whether the value of underlying assets is falling. However, like GDP, single metrics rarely tell the whole story. The detailed wealth accounts provide policy makers and analysts the tools to drill down to specific categories to examine how the underlying asset value is evolving over time and its relative importance in the national portfolio.

Weak versus Strong Sustainability

Box 1.1, in chapter 1, noted that change in wealth per capita is a measure of what is called *weak sustainability*, which assumes *complete substitutability* among asset classes. That is, cropland can be converted into residential homes with no major loss of economic well-being. This assumption is likely to be reasonable at fairly high levels of aggregation (of asset classes and spatial extent) and large volumes of assets, but less so when drilling down to specific locations. For example, biodiversity offsets are based on the assumption that losses in one place can be compensated by improvements in other places. At the other end of the spectrum, strong sustainability assumes that *no substitution* is possible without severe economic losses. This concept is useful when considering complementary assets in specific locations, such as fish stocks and fishing boats—loss of fish stocks cannot be compensated by adding more boats.

The CWON wealth accounts have largely been used at a highly aggregated level. Greater spatial disaggregation and disaggregation by asset classes would help determine where weak sustainability is more problematic and a strong sustainability approach is needed. To support such assessments, the CWON website will make available much of the underlying biophysical data used to construct the natural capital accounts, including direct links to data sources such as the Food and Agriculture Organization and data sets where appropriate.

Spatially disaggregated measures of critical natural capital are not yet available for action. The European Union recently updated the estimates of nine planetary boundaries (EEA 2020), which were originally developed by Rockström et al. (2009). At the global level, they indicate where safe boundaries have been passed for critical ecosystem services. Although global figures are useful for communicating the urgency of action, actions to address these issues must be taken at the national and subnational levels. Without information about ecosystem thresholds at the national and subnational levels, it is difficult to prioritize actions.

Fiscal Sustainability and Natural Capital

Comprehensive wealth accounts can also shed light on the sustainability of fiscal policies and management. The conventional measures used in public finance do not account for depletion or degradation of natural capital, although the source of government revenues may be unsustainable if it comes from a nonrenewable asset, such as fossil fuel extraction, or if it comes from an asset that is being mismanaged, such as a fisheries sector that is suffering from overfishing.

By introducing information about the assets underlying government revenue sources, wealth accounts can help guide more sustainable policy making, including in fiscal management. The International Monetary Fund (IMF 2018) carried out such an estimate for a large number of countries in 2018. The IMF has consistently made the argument that the fiscal balance of resource-rich countries, in particular, should include depletion of natural capital (a public resource in all but a handful of countries). This issue is explored further in chapter 11.

Conclusion

This chapter explained wealth accounting in detail and the factors that make up the sustainability indicator *change in wealth per capita*. The purpose was to provide a clear sense of what the indicator includes, what it does not include, and how to interpret it. Wealth accounts are built on the concepts and methods laid out in the SNA and SEEA and, as such, measure the financial value of the stock of assets available for production and consumption, but they are not intended to measure broad human welfare. Similarly, the indicator of sustainability is necessary but not sufficient on its own to assess sustainability; complementary indicators for social capital, biodiversity, and critical natural capital are needed. Social capital measures are explored in chapter 15, and the underlying biophysical data will be made available for other analytical work that informs sustainability.

Notes

1. The data set can be accessed at http://www.worldbank.org/cwon/.
2. Previous editions of the CWON classified assets into four classes. Here, natural capital is split into renewables and nonrenewables because they differ greatly in terms of management for development.
3. Global databases of estimated losses of produced capital from natural disasters are compiled by organizations such as Swiss Re and EM-Dat and the International Disaster Database (https://www.emdat.be), but the estimates are not consistent with SNA produced capital.
4. The perpetual inventory method that is used to estimate produced capital from annual investment adjusts only for "normal depreciation," not catastrophic events.

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3

Global and Regional Trends in Wealth, 1995–2018

Glenn-Marie Lange, Diego Herrera, and Esther Naikal

Main Messages

- Global wealth—produced capital, renewable and nonrenewable natural capital, human capital, and net foreign assets—grew 91 percent from 1995, reaching US$1,152 trillion by 2018, accompanied by a significant reduction in the share of wealth held by high-income countries. Middle-income countries are converging with high-income countries, albeit slowly. But low-income countries are still lagging.
- Most countries increased per capita wealth between 1995 and 2018, with the fastest growth in upper-middle-income countries. But for 26 countries, representing all income groups, per capita wealth stagnated or declined.
- Despite this, growth in gross domestic product (GDP) outstripped growth in wealth among most countries. This was most pronounced among low-income countries, the group with the largest proportion whose GDP growth exceeded wealth growth between 1995–2018.
- These findings are cause for concern for both convergence of prosperity and the sustainability of economic growth. To catch up with richer nations, low-income countries need to be accumulating assets faster than other countries; however, we find the opposite. Some countries record declining wealth per capita.
- Renewable natural capital increased in value since 1995 in all income groups and accounted for 3 percent of total wealth in 2018. Nonrenewable natural capital assets grew rapidly from 1995 until around 2014 and have been steadily declining in value since then, driven by declining fossil fuel prices and posing a difficult development challenge for countries that are highly dependent on these assets.
- At the global level and for most countries, human capital, measured as the net present value of lifetime earnings of the labor force, is the most important component of wealth (64 percent in 2018).

Introduction

This chapter provides an overview of how the wealth of nations—the sum of produced capital, renewable natural capital, nonrenewable natural capital, human capital, and net foreign assets—changed from 1995 to 2018. It first covers the main trends in total wealth and per capita wealth accumulation across income groups and regions. The chapter then explores changes in the composition of total wealth over time, showing how the gains that were achieved differed across asset classes at various levels of economic development. Then the chapter discusses natural capital, the roles played by renewables and nonrenewables, and the importance of natural capital for low- and middle-income countries.

Growth of Global Total Wealth

Global wealth grew 90 percent from 1995 to 2018, reaching US$1,152 trillion (table 3.1). On a per capita basis, average wealth grew from

TABLE 3.1 Global Wealth, by Income Group, 1995–2018

	1995	2000	2005	2010	2015	2018
Wealth (2018 US$, billions)						
Low-income	2,941	3,285	3,828	4,868	6,175	6,814
Lower-middle-income	30,049	33,561	41,719	56,219	68,299	77,514
Upper-middle-income	108,870	132,912	174,524	243,603	323,819	365,811
High-income: non-OECD	13,133	15,331	19,069	25,925	32,399	30,418
High-income: OECD	448,497	514,805	552,929	589,210	637,919	671,447
World	**603,490**	**699,894**	**792,069**	**919,824**	**1,068,612**	**1,152,005**
Shares (%)						
Low-income	<1	<1	<1	1	1	1
Lower-middle-income	5	5	5	6	6	7
Upper-middle-income	18	19	22	26	30	32
High-income: non-OECD	2	2	2	3	3	3
High-income: OECD	74	74	70	64	60	58
World	**100**	**100**	**100**	**100**	**100**	**100**
Per capita wealth (2018 US$)						
Low-income	9,379	9,121	9,250	10,228	11,306	11,462
Lower-middle-income	15,253	15,516	17,721	22,066	24,896	27,108
Upper-middle-income	50,744	58,872	74,317	100,114	128,136	141,682
High-income: non-OECD	315,088	334,226	367,631	410,083	450,258	400,891
High-income: OECD	468,398	522,668	545,341	564,426	597,897	621,278
World	**111,174**	**120,431**	**128,122**	**140,129**	**153,631**	**160,167**

Source: World Bank staff calculations.
Note: The figures for wealth are in constant 2018 US dollars at market exchange rates. OECD = Organisation for Economic Co-operation and Development.

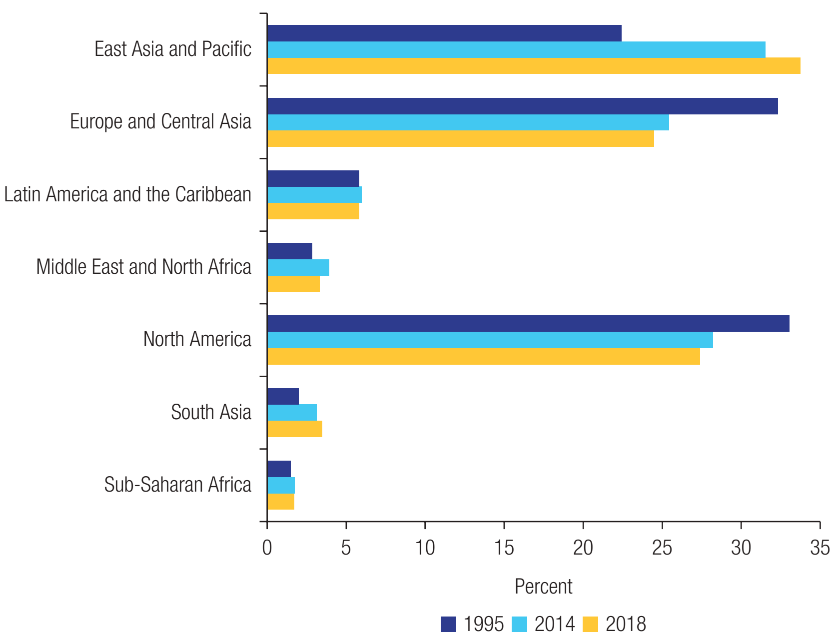
US$111,174 to US$160,167. This represents a real rate of growth of 2 percent per year.

The share of global wealth grew for East Asia and Pacific and South Asia and declined for North America as well as the Europe and Central Asia region (figure 3.1). The trends reversed, declining after 2014, for countries in the Middle East and North Africa and Sub-Saharan Africa, regions highly dependent on fossil fuels, because of the drop in fossil fuel prices around that year.

The wealth of middle-income countries, especially upper-middle-income countries, surged from 23 to 38 percent of global wealth. Meanwhile, the share of high-income Organisation for Economic Co-operation and Development (OECD) countries declined from 74 percent in 1995 to 58 percent in 2018 (figure 3.2). Low-income countries had less than 1 percent of global wealth in 2018, about the same share as in 1995, although their share of the world's population grew from 6 to 8 percent.

A closer look at middle-income countries shows that China's share of global wealth more than doubled, from 7 to 21 percent. Gains among lower-middle-income countries were much smaller, while upper-middle-income countries excluding China had a lower share in 2018 than in 2014 and 1995 (figure 3.3). China by far represents the largest share of wealth among low- and middle-income countries (figure 3.4).

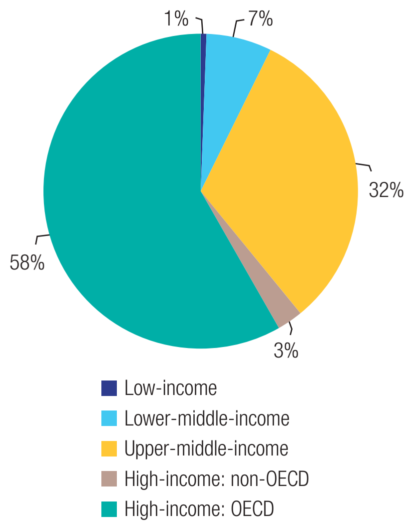
FIGURE 3.1 Shares of Global Wealth, by Region, 1995–2018



Source: World Bank staff calculations.

FIGURE 3.2 Distribution of Global Wealth, by Income Group, 2018

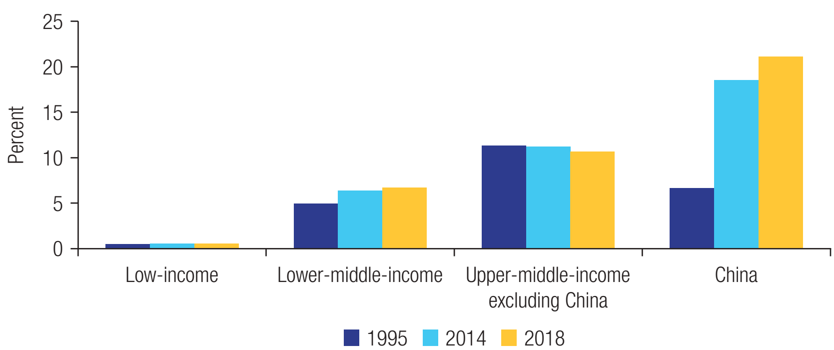
share of global wealth



Source: World Bank staff calculations.

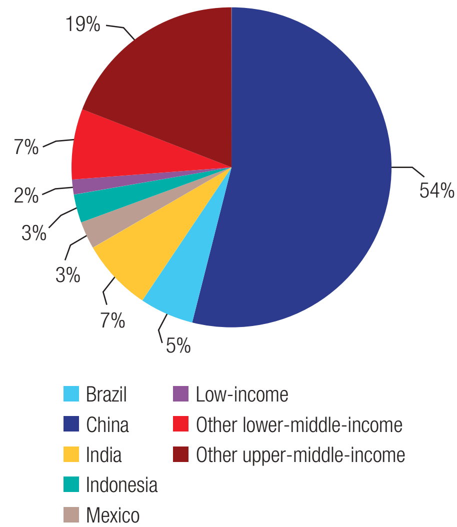
Note: OECD = Organisation for Economic Co-operation and Development.

FIGURE 3.3 Shares of Global Wealth in Low- and Middle-Income Countries, 1995–2018



Source: World Bank staff calculations.

FIGURE 3.4 Distribution of Wealth among Low- and Middle-Income Countries, 2018
share of wealth



Source: World Bank staff calculations.

Changes in Per Capita Wealth

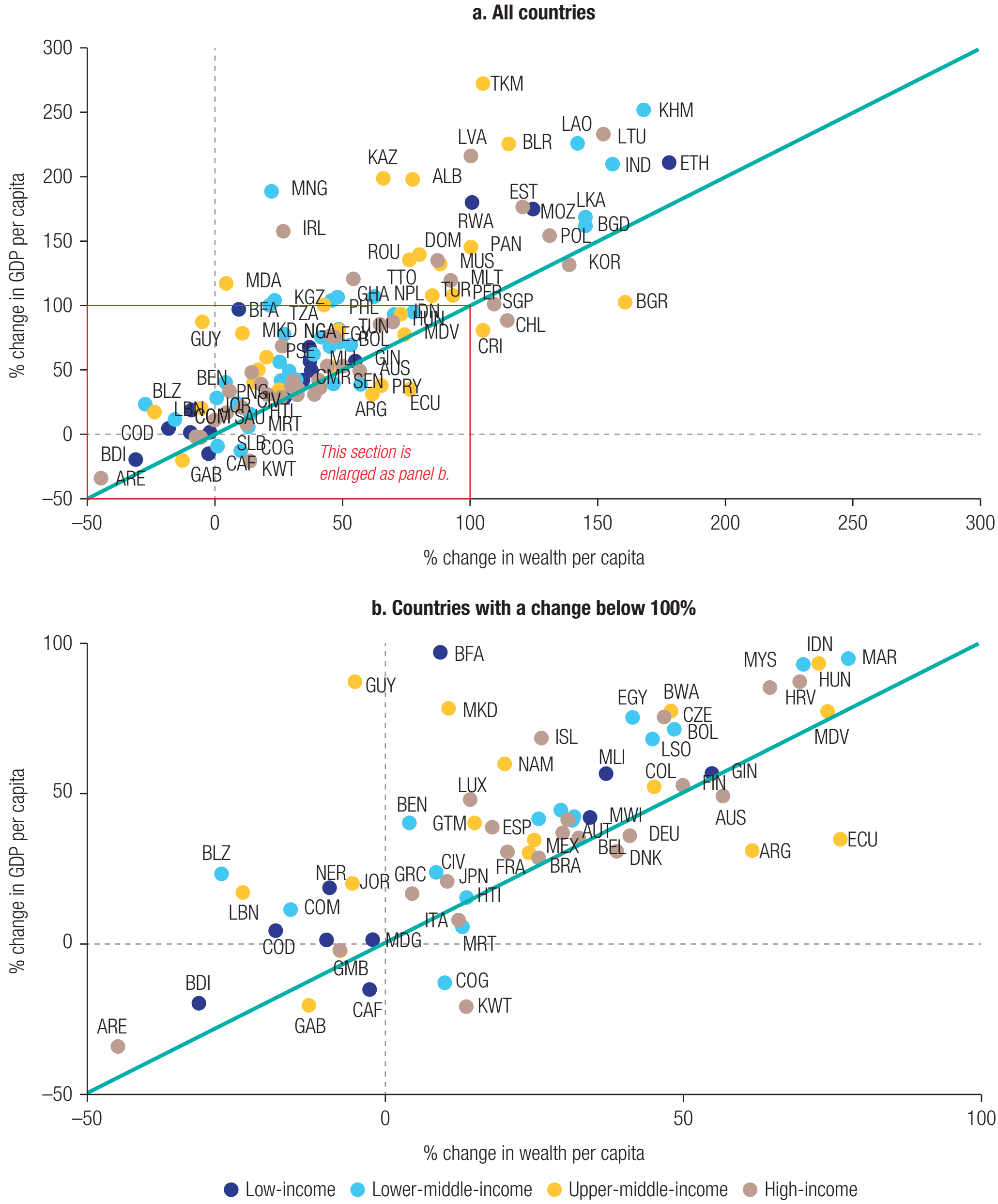
Wealth in per capita terms increased in a large majority of countries between 1995 and 2018. The fastest growth in per capita wealth was measured among upper-middle-income countries. This reflects the convergence in prosperity between rich and middle-income countries seen in this period. It is consistent with similar GDP growth convergence results (figure 3.5, panel a). Figure 3.5, panel b, shows that at least 10 countries had faster GDP growth than their wealth per capita growth between 1995 and 2018.

However, for 26 countries, drawn from across income groups, per capita wealth stagnated or declined. Eleven of these were in Sub-Saharan Africa. Sustainable economic development depends on building assets as well as driving GDP growth. There are sustainability concerns among these countries, whose GDP may be rising from short-term consumption or degradation of assets rather than from investments in capital stocks.

Furthermore, growth in GDP outstripped growth in wealth among most countries. This was most pronounced among low-income countries, the group with the largest proportion whose GDP growth exceeded wealth growth. This result holds for both total numbers and per capita values between 1995 and 2018 (see table 3.2).

Large disparities in per capita wealth around the world persist and in some cases have worsened. On average, an individual in an OECD country was implicitly endowed with US$621,278 in wealth at birth in 2018. For an individual born in a low-income country, the estimate was just US$11,462 (table 3.1).

FIGURE 3.5 Change in GDP per Capita and Wealth per Capita, 1995–2018



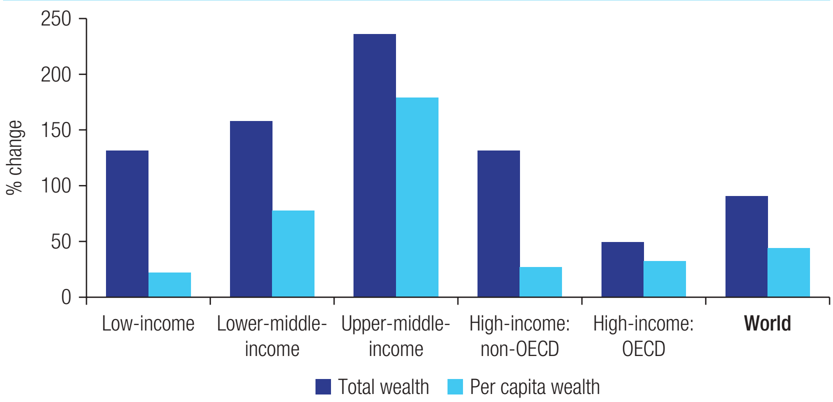
Source: World Bank staff calculations.
Note: Only countries with complete data for 1995 and 2018 are shown.

TABLE 3.2 Growth in GDP Compared with Growth in Total Wealth, by Income Group, 1995–2018

Income group	GDP % growth > total wealth % growth (number of countries)	GDP % growth < total wealth % growth (number of countries)	Proportion of countries with GDP % growth > total wealth % growth
Low-income	16	2	8.0
Lower-middle income	37	5	7.4
Upper-middle-income	33	7	4.7
High-income	32	9	3.6
World	**118**	**23**	**5.1**

Source: World Bank staff calculations.
Note: These numbers were calculated as the percent change increase of 1995 values against 2018 values for a total of 142 countries with complete data for these years.

FIGURE 3.6 Changes in Total Wealth and Per Capita Wealth, by Income Group, 1995–2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

Over time, population growth affects per capita wealth, especially in low- and lower-middle-income countries (figure 3.6). Between 1995 and 2018, global wealth grew by 91 percent, but population grew by 32 percent, so that the net increase in per capita wealth was only 44 percent. Per capita wealth grew fastest in middle-income countries, raising their share of global wealth, but the largest growth occurred in upper-middle-income countries (at 179 percent), in part because of China. Low-income countries increased their total wealth by nearly 132 percent—more than high-income OECD countries or the global average—but only by 22 percent on a per capita basis because population growth was highest in those countries.

The time analyzed can be disaggregated further into two periods: 1995–2014, which the previous edition of *The Changing Wealth of Nations* (CWON) covered, and 2014–18, the latest years of available wealth data. This provides insight into the most recent trends in per capita wealth. Table 3.3 shows the shift in average annual growth rates of total wealth per capita by income group for the two periods. The lower-middle-income and upper-middle-income groups have the highest annual growth rates, despite the upper-middle-income group falling a percentage point in the most recent years. Lower-middle-income and OECD countries maintained similar growth rates in both periods. The high-income non-OECD group experienced the most dramatic decline in its average annual growth rate in per capita wealth, from 1.9 to −2.7 percent. This resulted from the drop in fossil fuel prices—an impact that was not captured in the previous edition of the CWON. Low-income countries also saw a significant decline over recent years, dropping from 1.0 to 0.4 percent. This is especially concerning in light of the economic impact of the COVID-19 pandemic in 2020, which is likely to amplify this slowing trend in wealth.

Within each income group and region, growth of per capita wealth can vary greatly among countries (map 3.1). Per capita wealth changed little or fell in 26 countries, particularly some of the low-income countries in Sub-Saharan Africa as well as a few OECD countries affected after 2009 by the financial crisis (for example, Greece). Countries in Sub-Saharan Africa showed the most variation among the regions, with rapid growth in countries such as Ethiopia and Mozambique and losses in countries such as Zimbabwe. Gabon and Saudi Arabia experienced declines in wealth per capita resulting from the fall in fossil fuel prices around 2014.

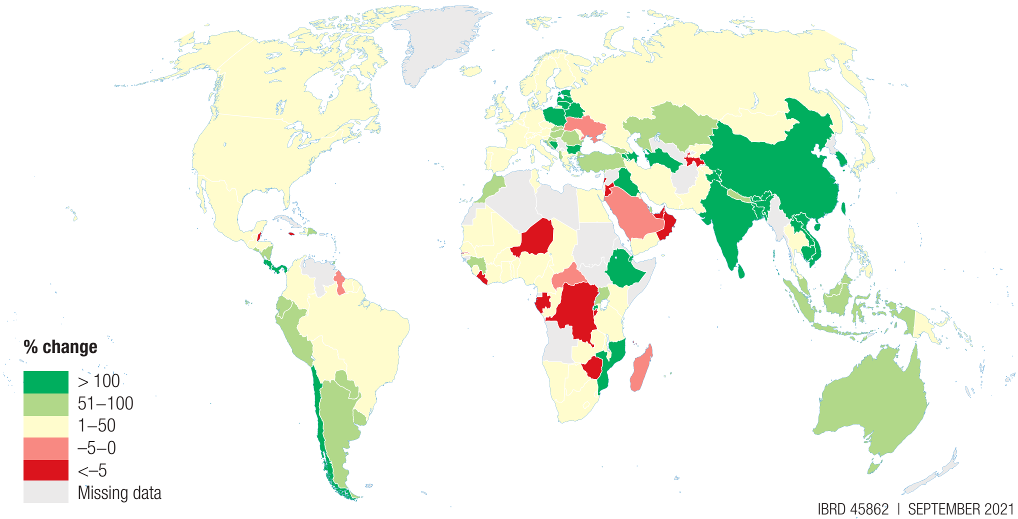
TABLE 3.3 Average Annual Growth of Per Capita Wealth, by Income Group, 1995–2014 and 2014–18

percent

Income group	1995–2014	2014–18
Low-income	1.0	0.4
Lower-middle-income	2.5	2.6
Upper-middle-income	4.8	3.6
High-income: non-OECD	1.9	−2.7
High-income: OECD	1.2	1.4

Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

MAP 3.1 Growth of Total Wealth per Capita, 1995–2018



Source: World Bank.

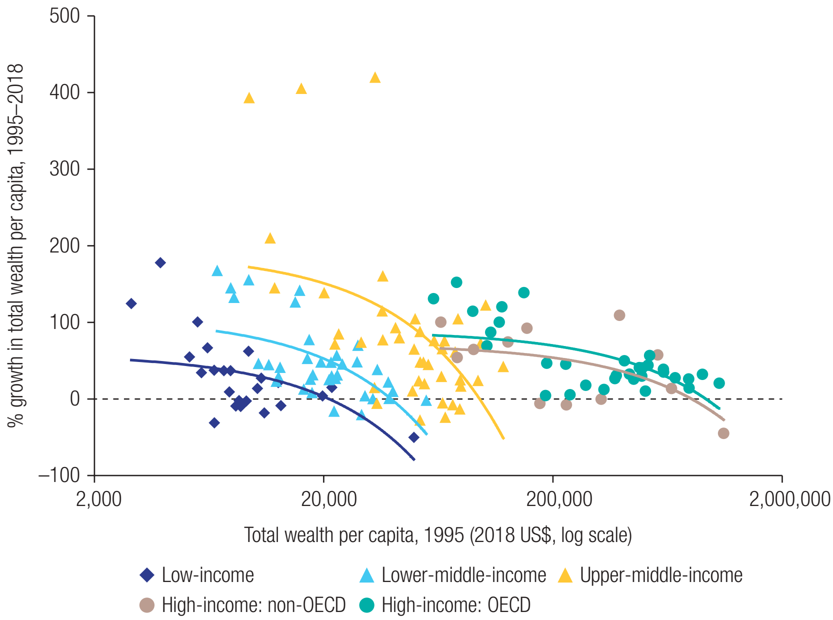
Convergence in the Wealth of Nations

Is there convergence in the growth of the wealth of nations on a per capita basis? Are comparatively poorer countries catching up with comparatively richer ones? The wealth data do not provide a long view of development history, but the 23 years of data presented in this report provide a glimpse of recent history.

Figure 3.7 is a scatterplot of countries' percentage growth in total wealth per capita from 1995 to 2018 in relation to their total wealth per capita in 1995. The countries are categorized by income group (as of 2018). The downward trend lines within each income group show that per capita wealth of the poorest countries has grown faster than that of the wealthier countries in their income group. This trend is evident across all income groups, with the highest growth rates among the upper-middle-income and lower-middle-income groups. China's fast growth drove the upper-middle-income trend.

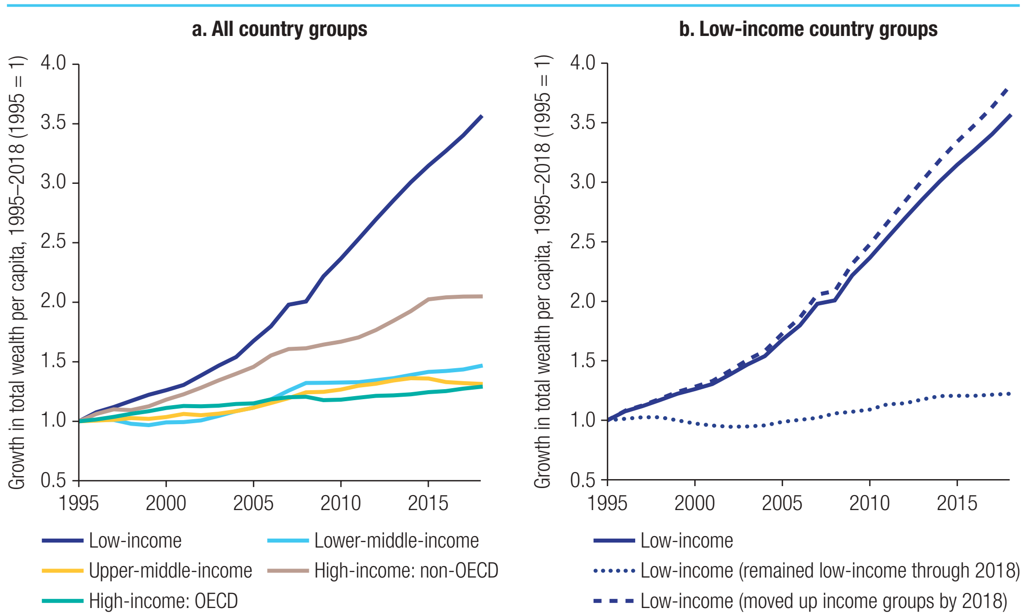
This chapter's discussion of wealth trends to this point has centered around income groups as defined in the latest year of data, 2018. Another approach—one more relevant to finding evidence of convergence—is to look at trends by income group as defined at the beginning of the time series, 1995. Figure 3.8 shows the growth in total wealth per capita by income group in 1995, indexed to 1995 (1995 = 1). In panel a, the growth in per capita wealth among low-income countries far exceeds that in all

FIGURE 3.7 Growth of Per Capita Wealth from 1995 to 2018 Relative to Per Capita Wealth in 1995



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

FIGURE 3.8 Growth of Total Wealth per Capita, Indexed to 1995, by Income Group in 1995



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

other income groups, confirming the convergence hypothesis that poorer countries tend to grow faster than richer countries. OECD countries have the lowest per capita growth rates, followed by upper-middle-income countries (as defined in 1995). High-income non-OECD sticks out as the second fastest growing group. This group, however, comprises only five countries, with the fast growth driven by the Republic of Korea.

A more nuanced analysis is required for the low-income group trend, which included China and India in 1995. With their large populations, the per capita growth rates of China and India hide underlying trends among other low-income countries. Figure 3.8, panel b, provides a closer look at the low-income country average, where low income is separated into two groups: countries that moved up income groups by 2018 and countries that remained in the low-income group through 2018. China and India are the dominant drivers among the 29 low-income countries that have moved up since 1995 to upper-middle-income and lower-middle-income status. There is a stark difference in growth between the group that moved to higher income levels and the countries that remained in the low-income group from 1995 to 2018. The latter group of 24 countries, primarily in Sub-Saharan Africa, have a per capita growth rate that is lower than all the other income groups and reveals a troubling trend of stagnant economic development.

While this short assessment does not delve into the rigorous econometric analysis of the convergence literature, the simple trends suggest that poorer countries are indeed catching up to richer countries in their per capita wealth over time, but some countries seem to be left behind.

Composition of Wealth

Human capital remains the most important component of wealth. Its share in total wealth increased from 62 percent in 1995 to 64 percent in 2018 (table 3.4). Produced capital's share decreased from 32 to 31 percent; renewable natural capital's share went from 4 to 3 percent; and nonrenewable natural capital's share increased from 2 to 3 percent.

Human capital is the largest asset category across income groups (figure 3.9). Low-income and high-income non-OECD countries have the lowest percentages (50 and 34 percent, respectively). These result from the large proportion of nonrenewable natural capital in high-income non-OECD countries and a large share of renewable natural capital in low-income countries. Figure 3.9 does not show net foreign assets, which are negative or close to zero for all groups except high-income non-OECD countries—oil producers that are net creditors to the world.

Although the share of human capital in total wealth typically increases with development, in some countries the share has declined, notably in China and in high-income non-OECD countries (figure 3.10). This is due to the aging of the population, slow wage growth, and other factors such as technology that favor produced capital over labor.

As economies grow, human capital per capita rapidly increases (figure 3.11). But in terms of the share of total wealth, high-income

TABLE 3.4 Global Wealth, by Asset Type, 1995 and 2018

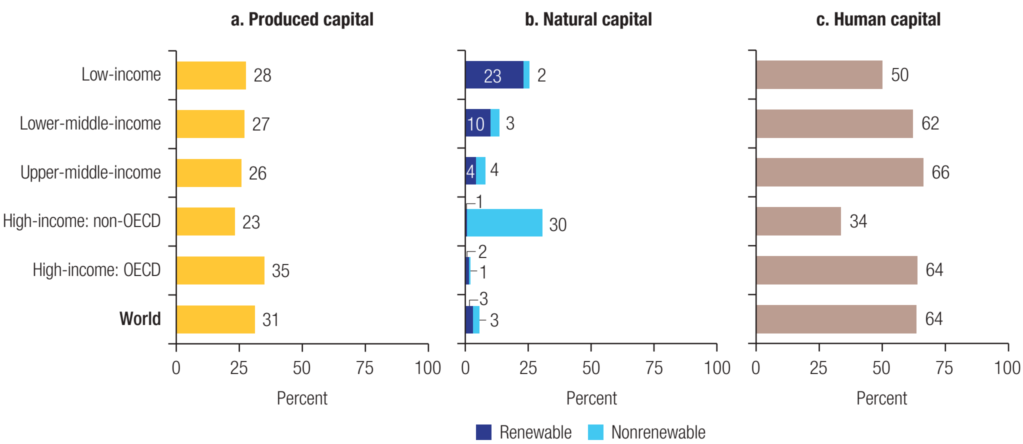
	1995		2018	
Type of asset	**2018 US$ (billions)**	**Percent**	**2018 US$ (billions)**	**Percent**
Total wealth	603,490	100	1,152,005	100
Produced capital	195,982	32	359,267	31
Human capital	371,572	62	732,179	64
Natural capital	38,409	6	64,542	6
Renewable natural capital	25,776	4	35,586	3
Forest timber	2,544	<1	2,728	<1
Forest ecosystem services	4,879	1	7,458	1
Water services	2,958	<1	5,133	<1
Recreation services	454	<1	1,057	<1
Nonwood forest products	1,467	<1	1,267	<1
Mangroves	213	<1	548	<1
Fisheries	1,225	<1	207	<1
Protected areas	1,927	<1	3,747	<1
Cropland	10,631	2	14,687	1
Pastureland	4,356	1	6,211	1
Nonrenewable natural capital	12,633	2	28,956	3
Oil	9,588	2	19,108	2
Natural gas	1,090	<1	3,288	<1
Coal	949	<1	3,482	<1
Metals and minerals	1,007	<1	3,078	<1
Net foreign assets	–2,473	<1	–3,983	<1

Source: World Bank staff calculations.
Note: The values are in constant 2018 US dollars at market exchange rates.

non-OECD countries have a much lower percentage compared with the other income groups. Lack of diversification and failure to build human capital put this group of countries at risk.

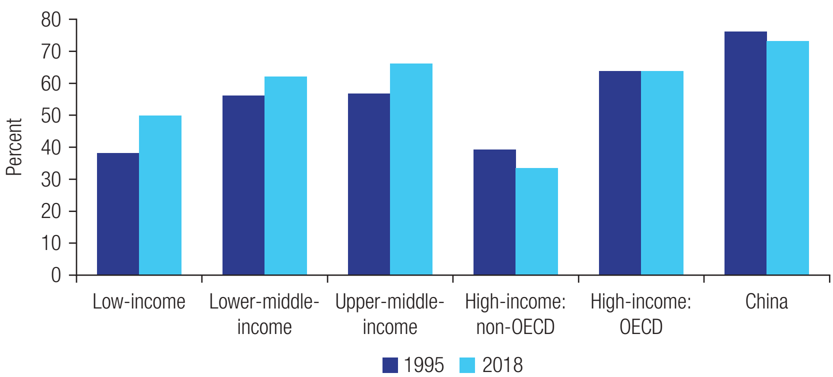
Natural capital represented 6 percent of total global wealth in 1995 and 2018. This share was equally divided between renewable and nonrenewable natural capital (3 percent each) in 2018 at the global level. Changes in natural capital between 1995 and 2018 can be analyzed using nested decomposition (table 3.5). This approach (Hoekstra 2021) distinguishes three decomposition effects: changes in either production or area (volume effect), changes in rent per unit of production or area (unit rent effect), and changes in the lifetime of the capital stock (lifetime effect). While the increase in the value of natural capital is largely driven by an

FIGURE 3.9 Shares of Wealth, by Asset Type and Income Group, 2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

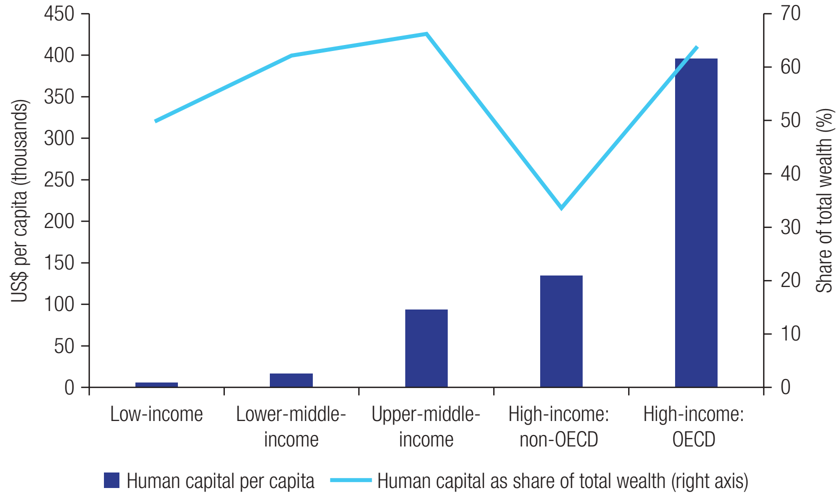
FIGURE 3.10 Share of Human Capital in Total Wealth, by Income Group, 1995 and 2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

increase in production or area (with the exception of mangroves), there is significant variation across assets in the effect of changes in unit rents or the lifetime of the stock. Unsurprisingly, renewable assets face little impact from changes in the lifetime of the stock as they regrow or replenish naturally, unlike depleting assets such as oil. However, even for nonrenewables, new resource discoveries and reserve additions can offset, or in the case of minerals, exceed the effects of depletion.

FIGURE 3.11 Human Capital: Share of Wealth versus Per Capita Value, by Income Group, 2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

TABLE 3.5 Three-Part Decomposition Results for Natural Capital Stocks, 1995–2018
constant 2018 US$ (millions)

		Rent effect			
	1995	**Volume effect**	**Unit rent effect**	**Lifetime effect**	**2018**
Natural capital	38,409	22,120	5,381	–1,370	64,542
Renewable natural capital	25,776	9,456	2,013	–1,660	35,586
Forests, timber	2,544	239	99	–154	2,728
Forests, nontimber	4,879	91	2,487	0	7,458
Mangroves	213	–13	348	0	548
Fisheries	1,225	62	–1,080	0	207
Protected areas	1,927	971	849	0	3,747
Cropland	10,631	6,018	–456	–1,506	14,687
Pastureland	4,356	2,088	–233	0	6,211
Nonrenewable natural capital	12,633	12,665	3,368	290	28,956
Oil	9,588	6,345	3,363	–188	19,108
Natural gas	1,090	1,695	559	–55	3,288
Coal	949	2,150	383	0	3,482
Metals and minerals	1,007	2,475	–937	533	3,078

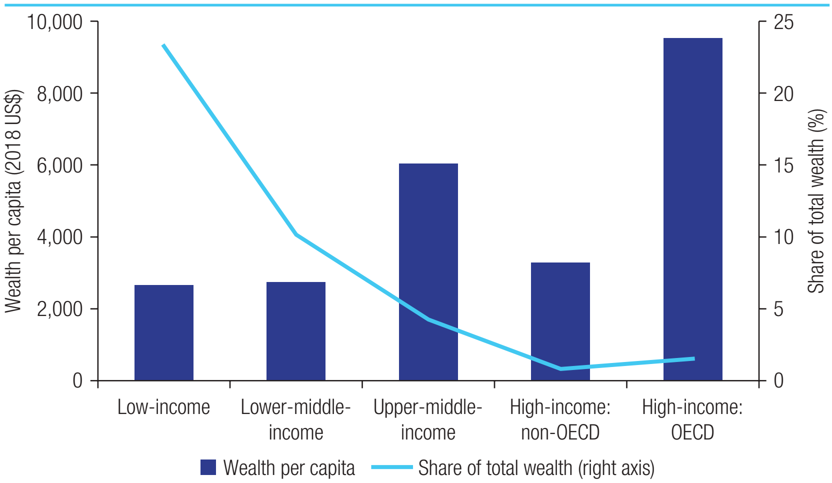
Source: World Bank staff calculations.
Note: Because the volume effect (in dollars) is weighted by unit rent, this can be positive even if physical quantities (e.g., catch in tons) show a negative trend. Moreover, the global volume effect shown here can be dominated by large countries. Green and pink cells represent positive and negative effects on natural capital, respectively.

Taken together, the three decomposition effects help us see more clearly the underlying drivers of changes in wealth. If the unit rent increases—for example, because of falling production costs or rising prices—the overall wealth increases, even if production is held constant. In the data for this report, wealth increased across all natural capital assets. However, not all decomposition factors contributed positively to this effect. Cropland, pastureland, and fisheries all saw declining unit rents at the global level, but this impact was offset by increased production or area under cultivation.

Renewable natural capital (forests, mangroves, fisheries, agricultural land, and protected areas) had a value of about US$35 trillion in 2018. Renewable natural capital remains important even as countries grow and develop, except in high-income non-OECD countries (figure 3.12). Although renewables' share of total wealth falls with income, the per capita values are highest in high-income OECD countries. Growing an economy is not about liquidating natural capital to build other assets. Development is about more efficient use of natural capital and its sustainable management.

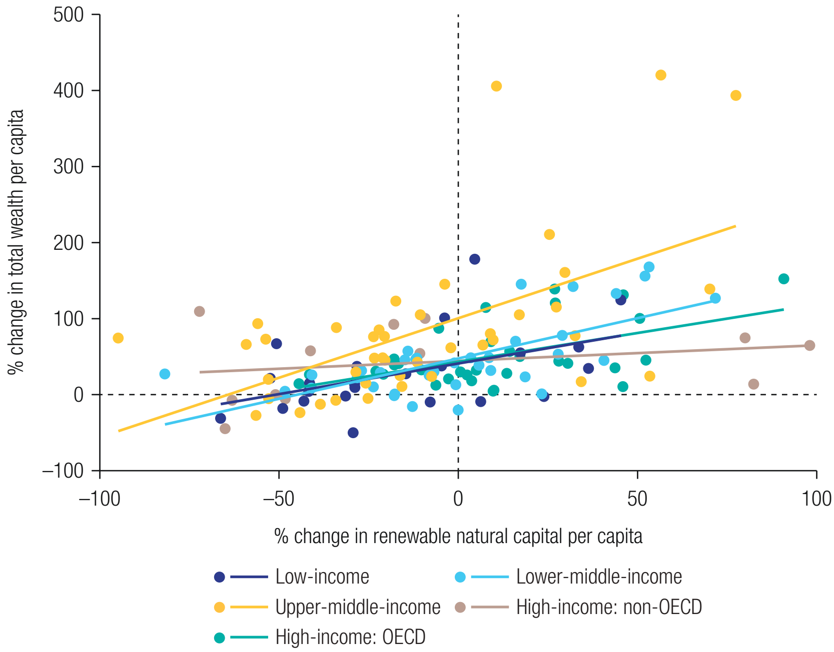
Growth is achieved by investing in renewable natural capital for resilient growth, not by depleting it (figure 3.13). For all income groups, the trend is for renewable assets to grow along with total wealth (shown by the positive trend lines in figure 3.13); that is, renewable natural capital is complementary to other assets (infrastructure or produced capital and human capital).

FIGURE 3.12 Renewable Natural Capital, by Income Group: Wealth Per Capita Value versus Share of Total Wealth, 2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

FIGURE 3.13 Growth of Renewable Assets and Total Wealth per Capita, by Income Group, 1995–2018

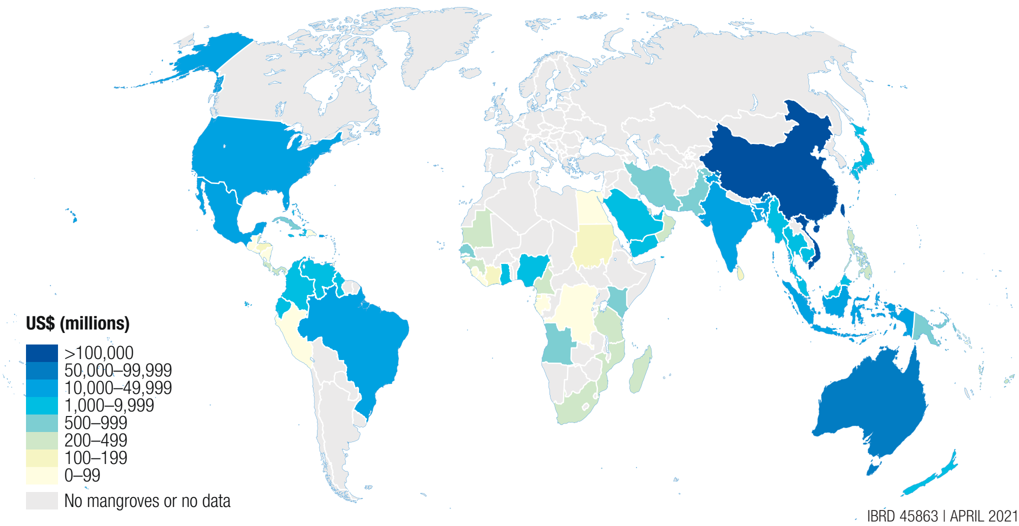


Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

In 2018 the largest component in the renewable natural capital category was cropland (41 percent), followed by forest ecosystem services (21 percent) and pastureland (17 percent). Among the subcategories of forest ecosystem services, water services represented the largest share of renewable natural capital (14 percent). Mangrove flood protection services grew the fastest between 1995 and 2018 among all categories of renewables (157 percent), followed by forest recreation services (133 percent). Mangroves, one of the new blue natural capital accounts in the CWON, provide services to countries across all income groups, but the highest wealth concentrations are in East Asia and Pacific, North America, and South America (map 3.2). Two categories of renewable natural capital decreased in value between 1995 and 2018: fisheries (−83 percent) and nonwood forest products (−14 percent), a subcategory of forest ecosystem services.

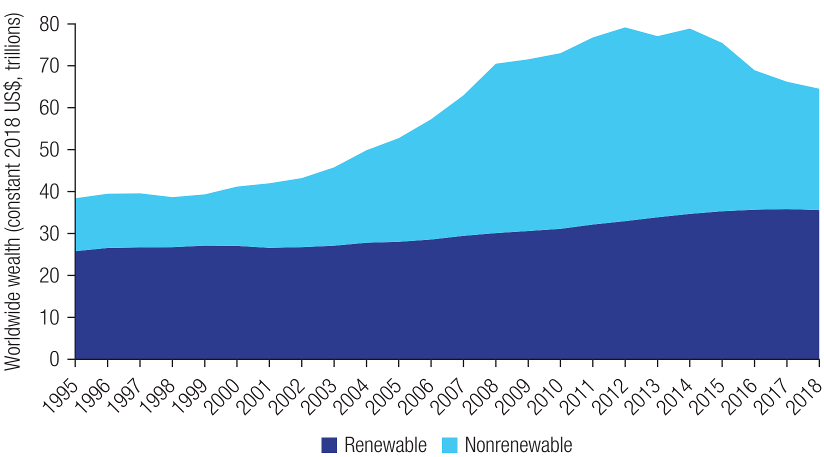
The world's nonrenewables (fossil fuels and minerals) are worth US$30 trillion (2018). Globally, nonrenewables represent 45 percent of natural capital and 2 percent of total wealth. About 37 percent of the world's nonrenewable wealth is found in Saudi Arabia, the Russian Federation, and China. Nonrenewable wealth in the world increased by 129 percent from 1995 to 2018 (figure 3.14). But these assets declined

MAP 3.2 Mangrove Wealth, 2018



Source: World Bank staff calculations based on Beck et al. 2021.

FIGURE 3.14 Renewable and Nonrenewable Natural Capital Wealth, 1995–2018



Source: World Bank staff calculations.

steeply after 2014—down from US$46 trillion to US$30 trillion (35 percent). Nonrenewable wealth benefited from the commodity boom from 2004 to 2014, and the growth came primarily from fossil fuels. Loss of value since 2014 also concentrated in fossil fuels.

Renewable Natural Capital Trade-Offs in Low- and Middle-Income Countries

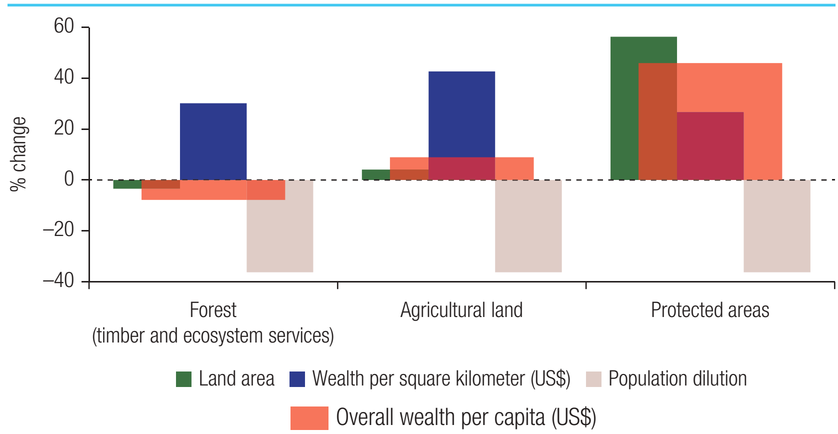
Renewable natural capital, in particular the land sector, is still an important share of total wealth in low- and middle-income countries. But these countries appear to be trading off some renewable assets for others. While forest (timber plus ecosystem services) wealth per capita decreased between 1995 and 2018, driven by population growth (population dilution effect) and a loss in forest area, agricultural land (cropland plus pastureland) wealth per capita increased because of area expansion and increasing value per square kilometer (figure 3.15). Protected areas show a rapid increase in area and wealth per square kilometer (more details on land accounts are provided in chapter 5).

The evidence for cropland and forest ecosystem services shows that if low- and middle-income countries fail to diversify their portfolio of assets and land assets are not managed sustainably, climate change and degradation can have a negative impact on wealth (see chapter 5 for details).

Savings and Changes in National Wealth

The key to increasing standards of living lies in building national wealth. This financial investment requires savings as well as good institutions and good governance to use assets productively. The previous discussion looked at changes in comprehensive wealth between 1995 and 2018; the chapter now examines some of the dynamics that drive changes in wealth from one period to the next. The most important dynamics, the endogenous or

FIGURE 3.15 Forests, Agricultural Land, and Protected Areas: Change in Land Area, Wealth per Square Kilometer, Population Dilution Effect, and Overall Wealth per Capita in Low- and Middle-Income Countries, 1995–2018



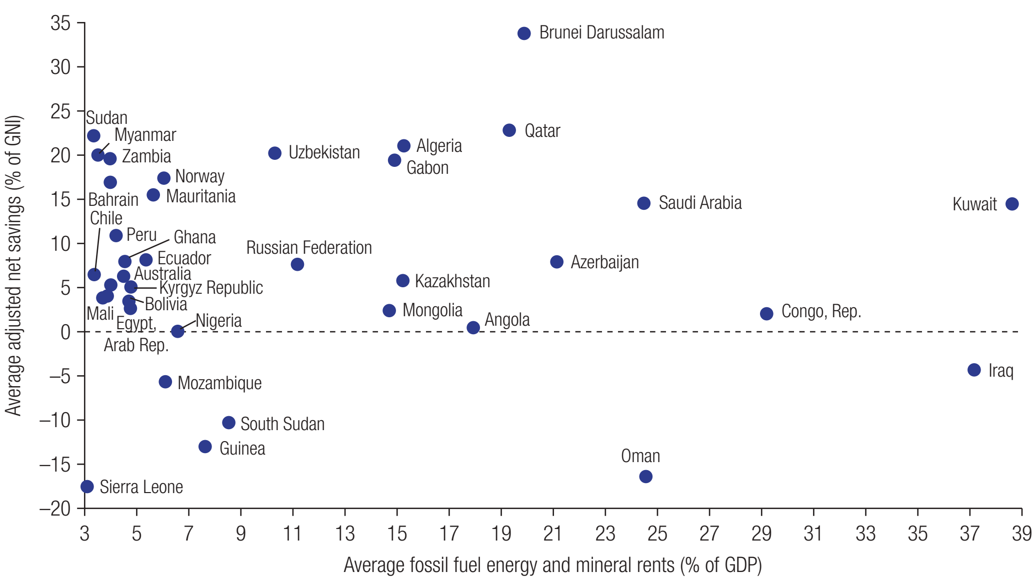
Source: World Bank staff calculations.

policy-induced dynamics, savings, and investment, are captured by adjusted net (or genuine) savings (ANS).

As a flow indicator, ANS is measured as gross national saving minus depreciation of produced capital, depletion of subsoil assets and timber resources, and the cost of air pollution damage to human health, as well as a credit for education expenditures. The rule for interpreting ANS is simple: if ANS is negative, the country is running down its capital stocks and possibly reducing future material well-being. If ANS is positive, then the country is adding to wealth and future material well-being. ANS is a complementary indicator to changes in per capita wealth, providing a simple framework for understanding the process of building wealth and how policy might influence each part of the process. This indicator—and its limitations—is discussed in depth in chapter 2.

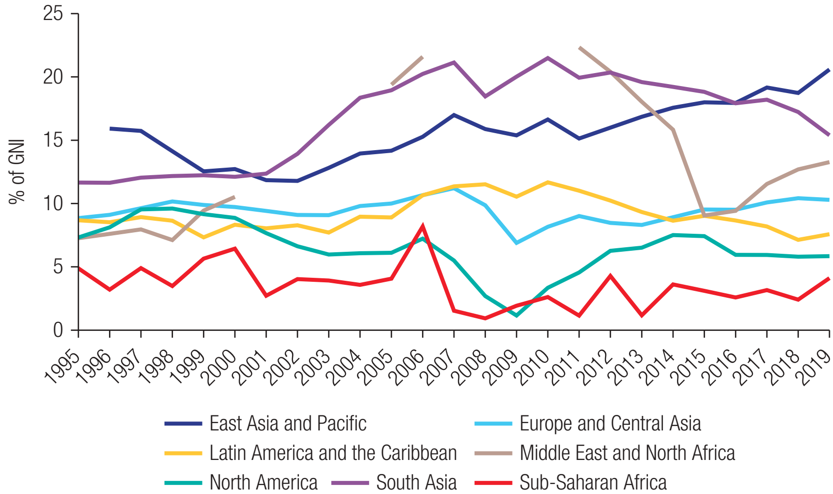
ANS can be a particularly useful indicator for resource-rich countries for which transforming nonrenewable natural capital into other forms of wealth is a major development challenge (see chapter 9 for additional analysis). Figure 3.16 plots countries with average nonrenewable resource rents greater than 3 percent of GDP against average ANS, from 2015 to 2019. In many countries, depletion of fossil fuel energy and mineral resources is offset by sufficient savings and investment in other types of capital, allowing countries to maintain a positive ANS (that is, above the zero line). But in countries with negative ANS, such as Guinea and Oman, natural capital is being depleted without being replaced, suggesting that these countries may become poorer over time.

FIGURE 3.16 Average Adjusted Net Savings in Resource-Rich Countries, 2015–19



Source: World Bank staff calculations.
Note: GDP = gross domestic product; GNI = gross national income.

FIGURE 3.17 Adjusted Net Savings, by Region, 1995–2019



Source: World Bank staff calculations.
Note: There is a break for the Middle East and North Africa because of a lack of data for many countries in the region for those years. GNI = gross national income.

Figure 3.17 presents regional trends in ANS over the past two decades. One sees a slight divergence starting in the early 2000s. Average ANS in East Asia and South Asia showed steady gains, while Europe and Central Asia, Latin America and the Caribbean, and North America remained relatively stagnant after recovering from the global financial crisis. Sub-Saharan Africa stands out, with its ANS at a consistently lower level—under 5 percent of gross national income over the past decade. Given that many countries in Sub-Saharan Africa are resource-dependent, this trend suggests that its development policies are not yet robustly promoting sustainable economic growth.

Conclusion

CWON 2021 shows that global wealth—produced capital, renewable and nonrenewable natural capital, human capital, and net foreign assets—grew 90 percent between 1995 and 2018, with growing shares for East Asia and South Asia and declining shares for North America and Europe. The trends reversed after 2014 for other regions (the Middle East and North Africa, Latin America and the Caribbean, and Sub-Saharan Africa), largely attributable to high dependence on fossil fuels.

Most countries increased per capita wealth between 1995 and 2018, with the fastest growth in upper-middle-income countries. But for 26 countries, representing all income groups, per capita wealth stagnated or declined. In Asian countries, wealth growth roughly kept pace with population growth, but African nations show a mixed performance. Where population growth is more rapid, greater investment in assets is needed for sustainability.

Middle-income countries are converging with high-income countries, albeit slowly, driven by China. Low-income countries are still lagging. Low- and middle-income countries (categorized as of 2018) saw the greatest growth rates in per capita wealth over 1995–2018. Countries that started as low income in 1995 show huge growth in per capita wealth on average, dwarfing all other income groups. But the overall trend hides two divergent groups: 29 countries moved up from low income, with a rapid average growth rate, driven by China, India, and countries in Europe and Central Asia, and 24 countries stayed low income, with very slow per capita growth, the majority in Sub-Saharan Africa and categorized as fragile, conflict-affected states and/or resource dependent.

Human capital, a key driver of development, represents 64 percent of global wealth. High-income non-OECD countries, which are heavily dependent on nonrenewables, are at risk from not diversifying and building human capital.

Natural capital is a key endowment for lower-income countries, and harnessing nature to invest in other assets is a key component of economic development. But building an economy is not about liquidating natural capital to build other assets. Natural capital per capita increases with income level, but the share declines as other assets are added.

To ensure both a convergence of prosperity and the sustainability of economic growth in lower-income countries, a significant increase in investments in human, produced, and natural capital will be needed to address the challenges posed by growing populations, depleting nonrenewable wealth, and the implications of climate change.

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4

Valuing Wealth Using Purchasing Power Parities

Esther Naikal, Glenn-Marie Lange, Nada Hamadeh, and Marko Rissanen

Main Messages

- This edition of *The Changing Wealth of Nations* (CWON) is the first to include an exploratory approach to valuing wealth using purchasing power parities (PPPs). It uses PPPs to control for price-level differences across countries to better compare economic well-being.
- Valuing wealth using PPPs shows a redistribution of global wealth: South Asia's share of PPP-based global wealth is 2.3 times higher than in market exchange rates (MERs) in 2018, and Sub-Saharan Africa's PPP-based share almost doubles.
- Looking at inequality across income groups, the Organisation for Economic Co-operation and Development's (OECD's) MER-based total wealth per capita in 2018 was 58 times greater than the low-income average—but this gap narrows to 21 times when valued in PPPs.

Introduction

All previous editions of the CWON estimated national wealth only in MERs. This report complements MER-based wealth accounts by applying PPPs to value the wealth accounts. MERs convert wealth into a common currency (for example, US dollars), facilitating global comparisons. Values in MER are most useful for understanding macroeconomic and fiscal policy issues. These might include quantifying the collateral available for international loans or estimating a country's ability to repay loans in foreign currency. Asset values at MERs are also relevant for other kinds of domestic policy analysis relying on comparable market prices and valuations. MER-based wealth therefore remains the default presentation of the CWON data set.

However, MERs are not always useful for cross-country comparisons of material well-being because they do not reflect the relative purchasing power of the currency in each country. One US dollar in the United States can buy much more in India, for example, than in Norway. For comparison of material well-being, PPPs are used to value total wealth by incorporating a common currency and eliminating price-level differences across countries.

This chapter starts with the motivation for using PPPs to complement MER valuation and presents the methodology for applying PPPs. It then reviews the results based on data from the CWON 2021 core accounts to determine how much PPPs might change the development story. The chapter closes by identifying conceptual and empirical issues that arise in applying PPPs to national wealth. These should be addressed in future work.

Valuing Wealth in Purchasing Power Parities

To adjust for differences in the cost of living and gain a better understanding of material well-being across countries, the International Comparison Program (ICP) (box 4.1) estimates global PPPs for a broad category of goods and services.

PPPs measure the total amount of goods and services that a single unit of a country's currency can buy in another country. The PPP between countries A and B measures the number of units of country A's currency required to purchase a basket of goods or services in country A compared with one unit of country B's currency to purchase a similar basket of

BOX 4.1 International Comparison Program and Purchasing Power Parities

The International Comparison Program (ICP) is a worldwide statistical initiative led by the World Bank under the auspices of the United Nations Statistical Commission, with the main objective of providing comparable price and volume measures of gross domestic product (GDP) and its expenditure aggregates among countries within and across regions. Through a partnership with international, regional, subregional, and national agencies, the ICP collects and compares price data and GDP expenditures to estimate and publish the purchasing power parities of the world's economies. The 2017 ICP round covered 176 economies for reference year 2017. The next ICP round is being conducted for reference year 2021.

Note: Additional information can be found at https://www.worldbank.org/en/programs/icp.

goods in country B. PPPs can thus convert the cost of a basket of goods and services into a common currency, eliminating price-level differences across countries. In other words, PPPs equalize the purchasing power of currencies. Due to large differences in price levels across economies, MER-converted gross domestic product (GDP) does not accurately measure the relative sizes of economies and levels of material well-being. PPPs make it possible to compare the output of economies and their inhabitants' welfare in "real" terms.

The common currency used for the PPP global comparison is the US dollar, so each economy's PPP is standardized by dividing it by that economy's US dollar exchange rate.

In the context of the World Bank's comprehensive wealth accounts, which are the sum of a broad range of assets, including produced, natural, human, and net foreign assets, the approach to estimating wealth accounts in PPPs depends on the purpose of the analysis. The main motivation for using PPPs is similar to the ICP's objective to control for price-level differences across countries and provide comparable international volume measures of GDP and its expenditure components. The objective of estimating wealth using PPPs is to construct comparable cross-country estimates of wealth that are not impacted by the different price levels between the countries or the volatility of MERs.

However, using PPPs in wealth accounting requires several theoretical and empirical considerations, none of which have been exhaustively addressed. The foremost issues are whether using PPPs for wealth is conceptually appropriate for cross-country comparisons, which level(s) of PPPs should be used, and how the constant value time series should be constructed based on PPPs. An additional consideration is what assumptions should be made about future relative prices using PPPs, given the forward-looking nature of wealth accounts. The core CWON wealth accounts generally assume constant future prices, given the lack of information and/or difficulty in making consistent projections on a global scale. Strong assumptions would also need to be applied when using PPPs.

At this initial experimental and exploratory stage, two approaches can be considered when applying PPPs to the wealth accounts. One would be to design PPPs that allow converting each asset into comparable international aggregates, decomposing each component into price and quantity, and constructing a stock price index. This approach addresses the productive value of assets and would be useful for productivity measurement analyses (such as total factor productivity) and comparing outputs and inputs across countries. However, this approach would require significant research and statistical work beyond the scope of this initial stage.

A second approach would be to take a consumption-based approach and view total wealth as a measure of future consumption possibilities. This approach is more useful for comparing real income across countries; it is also empirically easier to implement. This chapter follows the consumption-based approach for estimating PPP-based wealth for all countries, recognizing the need for further research.

The next decision is to choose the level of PPP. The ICP publishes global PPPs (US$ = 1) for a total of 44 expenditure components, in line with the System of National Accounts (SNA) framework, where GDP is measured from the expenditure side. The main aggregates in the ICP classification of final expenditure on GDP include the following consumption-related headings:

- Individual consumption expenditure by households
- Individual consumption expenditure by nonprofit institutions serving households (NPISH)
- Individual consumption expenditure by government
- Collective consumption expenditure by government

Given the choice of using consumption-oriented PPPs, a decision needs to be made on the government sector. Based on expert consultations, it would be ideal to use total consumption-level PPPs that include households, NPISH, and both government sectors (individual consumption + collective consumption), with the reasoning that, by and large, all government activities provide some utility to households. However, currently the ICP does not officially publish total consumption-level PPPs. Therefore, the wealth accounts are valued using the closest published heading: actual individual consumption-level PPPs, where actual individual consumption (AIC) covers the individual consumption expenditures of households, NPISHs, and government. Comparing this PPP to total consumption PPP, AIC excludes the collective consumption expenditure by the government. Therefore, the chapter uses AIC-level PPPs as a proxy measure for the current estimates.

This first attempt at estimating PPP-based wealth just scratches the surface of the technical questions and complicated methodological issues surrounding the correct measurement and usage of PPP-based national wealth. But this approach has the advantage of being simple to implement and straightforward to understand. By providing the first set of global PPP-based wealth data, the aim is to illustrate the importance of considering differing costs of living across countries and to provide additional wealth metrics to the development narrative.

Data and Methodology

The methodology for estimating PPP-based wealth accounts is relatively straightforward, given the decision to follow a simplified consumption-based approach to valuing wealth in PPPs.

Total wealth based on PPPs is calculated by dividing total wealth in constant 2018 US dollars at MERs—already estimated in the CWON 2021 core accounts—by the price-level ratio of the 2018 AIC-level PPP conversion factor to the MER. OECD and Eurostat publish annual data (including for 2018) on AIC PPPs for selected countries; ICP data on PPPs are available globally for 2017, so the 2018 value is extrapolated using countries' consumer price indexes. Additional gap-filling steps are

TABLE 4.1 Data Sources for Estimating Wealth in Purchasing Power Parities

Indicator	Data source	Notes
Total wealth	CWON 2021	Estimated in constant 2018 US dollars at market exchange rates
Actual individual consumption-level PPPs	ICP 2017, OECD, Eurostat	
GDP-level PPPs	World Bank's WDI	Used when AIC-level PPPs are not available
Market exchange rates	ICP 2017, OECD, WDI	
Consumer price index	WDI, IMF's macroeconomic and financial data	
GDP deflator	WDI	Used when CPI data are not available

Source: World Bank.
Note: AIC = actual individual consumption; CPI = consumer price index; CWON = Changing Wealth of Nations; GDP = gross domestic product; ICP = International Comparison Program; IMF = International Monetary Fund; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity; WDI = World Development Indicators.

implemented to maximize country coverage to make a meaningful comparison between the MER-based wealth as published in CWON 2021[1] and the PPP-based figures. The data sources used are listed in table 4.1.

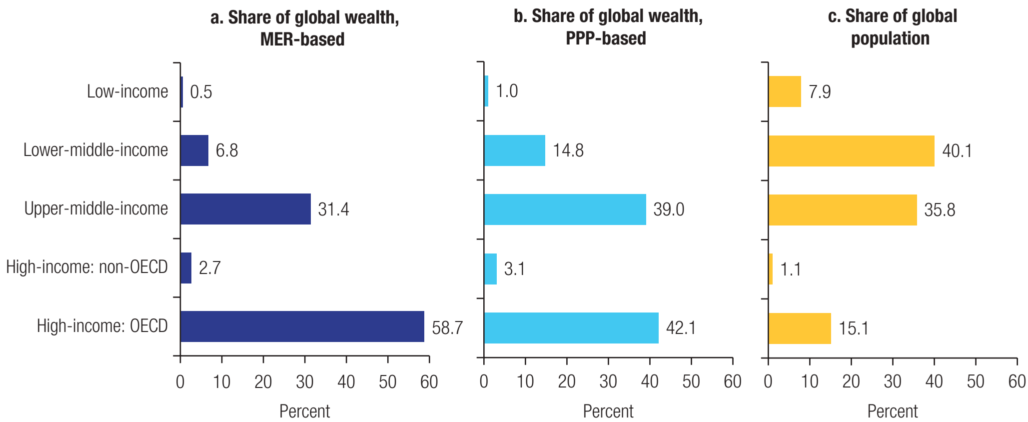
The following sections focus on the comparison of the wealth accounts based on PPPs to MERs.

Shift in the Global Distribution of Wealth

The PPP-based wealth results show a clear and expected shift in the global distribution of wealth in 2018. When wealth is measured using PPPs, the share of global wealth for low-income and lower-middle-income countries increases from 7.3 to 15.8 percent (figure 4.1). Upper-middle-income and high-income non-OECD countries increase their share of global PPP-based wealth by a smaller margin. The global share of wealth for OECD countries decreases from 58.7 to 42.1 percent. Inequality across income groups is still apparent, as the vast majority of the global population (84 percent) resides in low- and middle-income countries and yet holds a much smaller portion of the world's wealth—39 percent in MER-based wealth and 55 percent in PPP-based wealth.

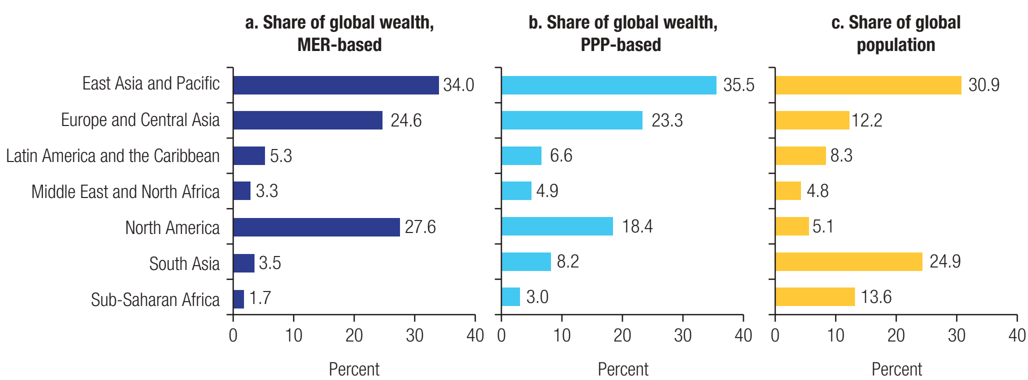
Figure 4.2 shows the shifting distribution of global wealth by geographic region. South Asia's share of PPP-based global wealth is 2.3 times higher than in MER in 2018, the highest increase across regions. Sub-Saharan Africa follows, almost doubling its share of PPP-based global wealth. But even with their share increases in PPP-based wealth, South Asia and Sub-Saharan Africa combined still hold only 11 percent of global wealth while containing almost 40 percent of the global population. Only

FIGURE 4.1 Share of Global MER-Based and PPP-Based Wealth and Population, by Income Group, 2018



Source: World Bank staff calculations.
Note: MER = market exchange rate; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity.

FIGURE 4.2 Share of Global MER-Based and PPP-Based Wealth and Population, by Region, 2018



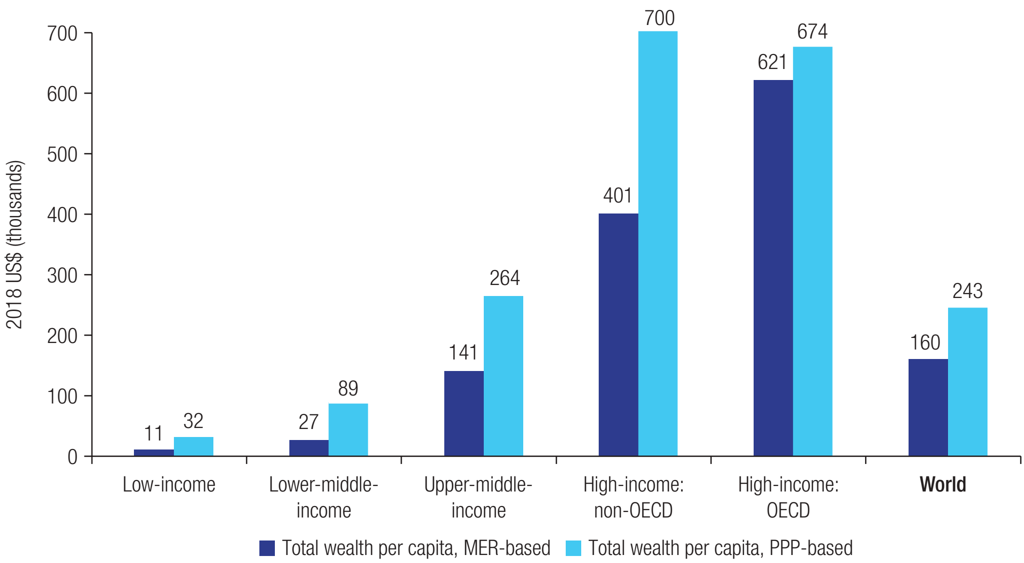
Source: World Bank staff calculations.
Note: MER = market exchange rate; PPP = purchasing power parity.

two regions show decreases in their shares of PPP-based global wealth: Europe and Central Asia, driven by Western European countries, and North America.

Narrowing Differences in Total Wealth per Capita across Groups

Figures 4.3 and 4.4 compare total wealth per capita in 2018 for MER-based and PPP-based wealth by income group and geographic region, respectively.

FIGURE 4.3 Total Wealth per Capita, MER-Based and PPP-Based, by Income Group, 2018



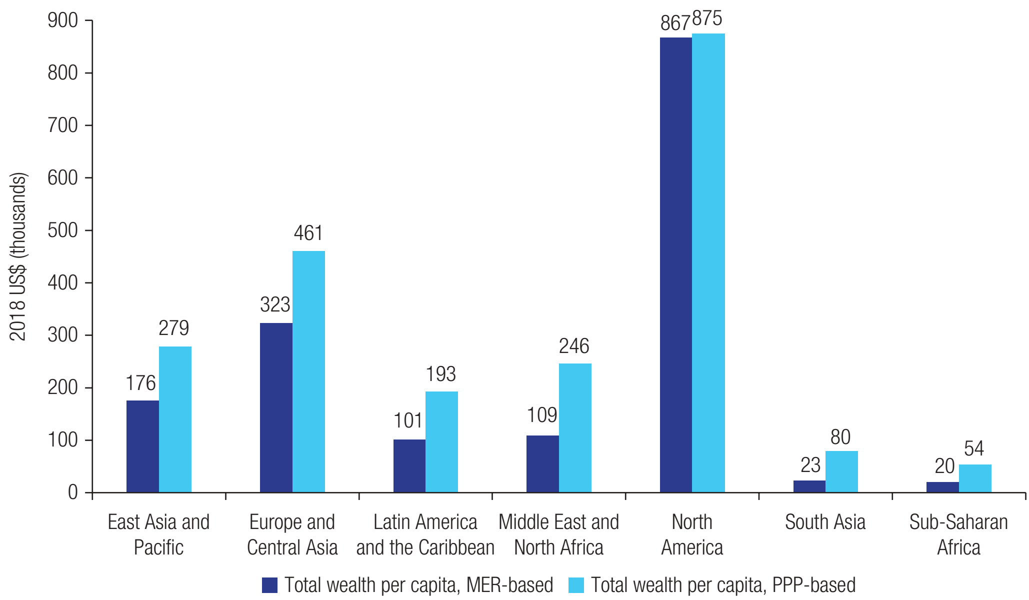
Source: World Bank staff calculations.
Note: MER = market exchange rate; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity.

In MER-based wealth, the global average wealth per person was US$160,437 in 2018. Valued in PPPs, the average total wealth per person increases 50 percent, to US$242,516. The largest gains in PPP-based wealth per capita compared with MERs are in the lower-middle-income group, where, driven by India, the PPP-based total wealth per capita is 3.3 times higher than in MERs in 2018. This is followed by the low-income group, where PPP-based wealth is three times higher. PPP-based wealth per capita in the upper-middle-income group increases by 88 percent, driven in large part by China, which contains over half the population of all upper-middle-income countries.

When wealth is based in PPPs, the wealthiest income group in 2018 becomes the high-income non-OECD group, with total wealth per capita at US$699,548 compared with the OECD's US$673,663. On the one hand, this results from many OECD countries' near-parity of their purchasing power with the United States as well as the handful of countries with *lower* PPP-based wealth compared with MERs (for example, Australia, Denmark, Iceland, Luxembourg, and Norway). On the other hand, this result reflects the US dollar's greater purchasing power across the board in high-income non-OECD countries. Specifically, Saudi Arabia drives the per capita trend in this aggregate group with 44 percent of its population and has a relatively lower price-level ratio of the AIC PPP conversion factor to MER at 0.45. This results in Saudi Arabia's PPP-based wealth per capita being estimated at US$726,435, compared with the MER-based US$324,194 in 2018.

The OECD's total MER-based wealth per capita in 2018 was 58 times greater than the low-income average. However, this gap narrows to 21 times when valued in PPPs; while it is still a large difference, the PPP-based measure demonstrates greater equality across income groups.

FIGURE 4.4 Total Wealth per Capita, MER-Based and PPP-Based, by Region, 2018



Source: World Bank staff calculations.
Note: MER = market exchange rate; PPP = purchasing power parity.

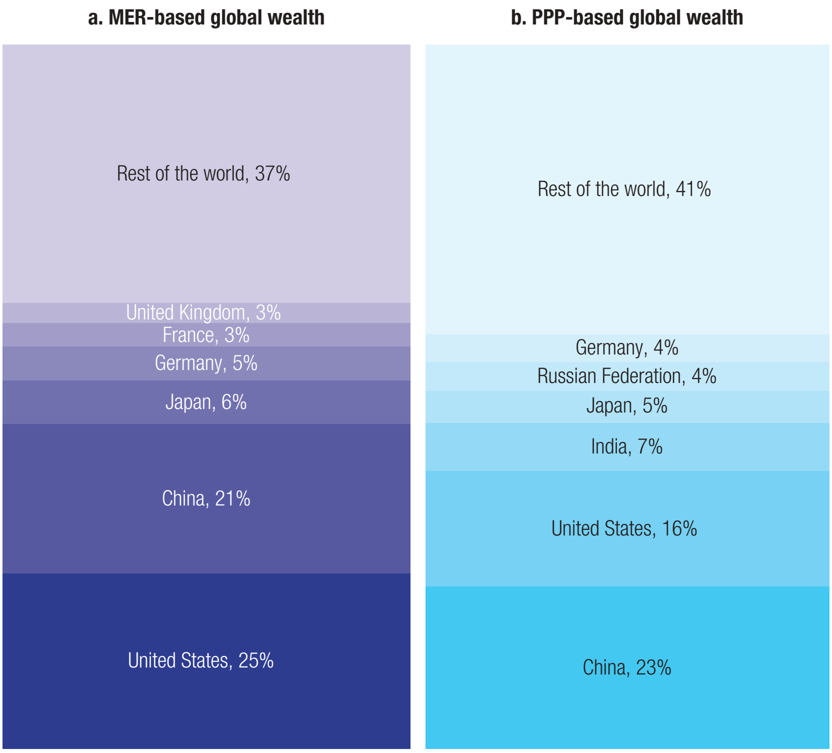
Looking at the comparison of MER- and PPP-based total wealth per capita by geographic region in 2018 (figure 4.4), South Asia again sees the greatest increase in PPP-based total wealth, at almost US$80,000 per capita compared with US$22,680 in MER. Average wealth per capita in Sub-Saharan Africa jumps 2.6 times higher in PPPs compared with MERs.

Country-Level Results

This section takes a closer look at the country-level results of PPP-based total wealth in 2018. The full set of country data is provided in annex 4A.

Figure 4.5 singles out the six economies with the largest shares of MER- and PPP-based global wealth in 2018. When wealth is measured in MERs, the United States holds the largest share of global wealth in 2018, at 25 percent, followed closely by China, at 21 percent. The four remaining countries (in the top six) hold significantly smaller global wealth shares, ranging from 3 to 6 percent. When wealth is measured in PPPs, China leaps ahead of the United States, with the largest share of global wealth, at 23 percent. The US share reduces to 16 percent (although its absolute amount remains the same in MER- and PPP-based wealth). India jumps to the third-largest share of PPP-based global wealth, at 7 percent, and the Russian Federation moves to fifth place.

FIGURE 4.5 Share of MER-Based and PPP-Based Global Wealth for the Six Largest Economies, 2018

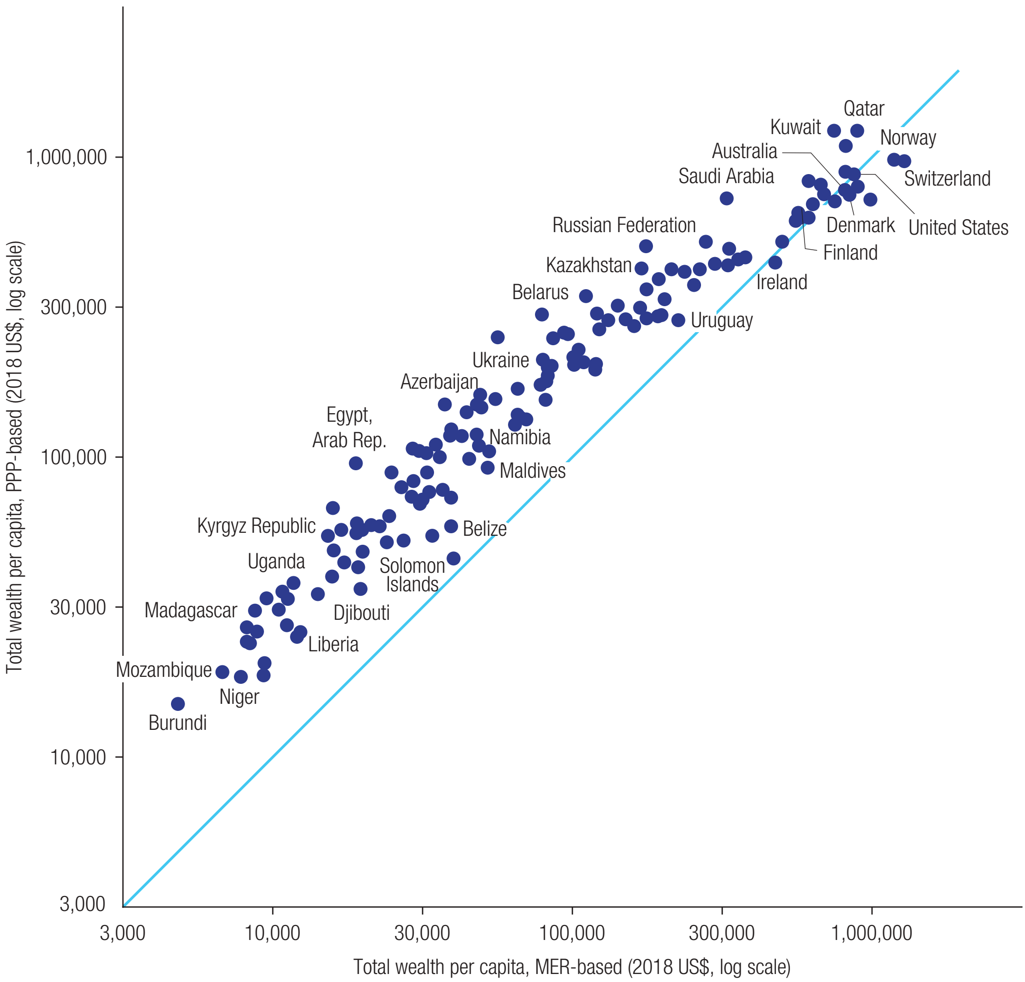


Source: World Bank staff calculations.
Note: MER = market exchange rate; PPP = purchasing power parity.

Figure 4.6 provides a scatterplot of all countries' total wealth per capita in 2018, with the MER-based value on the x-axis and the PPP value on the y-axis on a log scale. The 45-degree line denotes parity—that is, wealth is the same when measured in MERs and PPPs, such as for the United States. Countries above the line have wealth greater when valued in PPPs than when valued in MERs, with the opposite being the case for countries below the line.

All low- and middle-income countries lie above the blue line, with PPP-based wealth higher than MER-based wealth. The countries with the lowest total wealth per capita tend to be farthest from the 45-degree line, with movement toward and eventually crossing the line as wealth increases. Table 4.2 lists the 10 countries with the lowest price-level ratios (PPP conversion factor to MER, US = 1), or the greatest increases in PPP-based wealth per capita compared with MER. The Arab Republic of Egypt had the lowest price-level ratio, at 0.196 in 2018; its total wealth per capita jumps from US$18,271 in MER to US$93,317 when valued in PPPs. Of this group of countries with the lowest price-level ratios, Ukraine and Belarus stick out as relatively wealthier lower- and upper-middle-income countries, respectively.

FIGURE 4.6 Total Wealth per Capita, MER-Based and PPP-Based, 2018



Source: World Bank staff calculations.
Note: Countries above the line have wealth greater when valued in PPPs than when valued in MERs, with the opposite being the case for countries below the line. MER = market exchange rate; PPP = purchasing power parity.

On the other end of the spectrum, table 4.3 lists the eight countries with the highest price-level ratios in 2018 and where PPP-based wealth per capita is lower than in MER; these countries lie below the blue line in figure 4.6 and are all high-income European countries, except Australia. These results are not surprising, as prices and living costs are well known to be much higher in these wealthy countries.

Future Work

A natural progression at this point of the analysis would be to assess how PPP-based wealth per capita changed over time from 1995 to 2018,

TABLE 4.2 Countries with the Greatest Increases in PPP-Based Wealth per Capita Compared with MER-Based Wealth per Capita, 2018

			Total wealth per capita (2018 US$)		Price-level ratio (PPP conversion factor to MER)
Country	**Income group**	**Region**	**MER-based**	**PPP-based**	
Egypt, Arab Rep.	Lower-middle-income	Middle East and North Africa	18,271	93,317	0.196
Ukraine	Lower-middle-income	Europe and Central Asia	55,272	247,367	0.223
Tajikistan	Low-income	Europe and Central Asia	24,668	107,095	0.230
Kyrgyz Republic	Lower-middle-income	Europe and Central Asia	15,328	65,953	0.232
Azerbaijan	Upper-middle-income	Europe and Central Asia	36,315	146,583	0.248
Belarus	Upper-middle-income	Europe and Central Asia	77,516	294,580	0.263
Tunisia	Lower-middle-income	Middle East and North Africa	28,858	104,367	0.277
India	Lower-middle-income	South Asia	24,102	86,841	0.278
Nepal	Low-income	South Asia	15,280	54,941	0.278
Sierra Leone	Low-income	Sub-Saharan Africa	9,171	32,695	0.280

Source: World Bank staff calculations.
Note: MER = market exchange rate; PPP = purchasing power parity.

TABLE 4.3 Countries with Lower PPP-Based Wealth per Capita Compared with MER-Based Wealth per Capita, 2018

			Total wealth per capita (2018 US$)		Price-level ratio (PPP conversion factor to MER)
Country	**Income group**	**Region**	**MER-based**	**PPP-based**	
Iceland	High-income: OECD	Europe and Central Asia	987,021	719,302	1.372
Switzerland	High-income: OECD	Europe and Central Asia	1,280,371	967,508	1.323
Norway	High-income: OECD	Europe and Central Asia	1,185,533	980,739	1.209
Luxembourg	High-income: OECD	Europe and Central Asia	898,547	793,984	1.132
Denmark	High-income: OECD	Europe and Central Asia	842,148	753,244	1.118
Australia	High-income: OECD	East Asia and Pacific	827,510	764,827	1.082
Ireland	High-income: OECD	Europe and Central Asia	472,814	444,029	1.065
Sweden	High-income: OECD	Europe and Central Asia	748,540	713,695	1.049

Source: World Bank staff calculations.
Note: MER = market exchange rate; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity.

compared with MER-based wealth. However, the current approach to valuing wealth in PPPs does not change a country's relative growth over time compared with valuing wealth in MER, only the absolute level changes. Therefore, the analysis at this stage focuses on cross-country comparisons in 2018. Future work could dive deeper into constructing an appropriate PPP-based wealth time series, paying careful attention to price deflators and interpreting the results.

Valuing comprehensive wealth using PPPs is a new area of work at an experimental stage. There are conceptual and empirical challenges not rigorously addressed in this chapter due to the aim of providing an easily implementable approach to valuing wealth in PPPs and having a clear comparison with the MER-based wealth published in the CWON 2021 core accounts.

The PPPs used in this work reflect the underlying approach that wealth embodies a country's potential consumption, and therefore consumption-based PPPs are used to convert wealth. But there is a greater conceptual debate on how to use PPPs, how to interpret the PPP results, and what the resulting policy implications are. Additional research and expert consultations are required.

Careful consideration must be given to the assumption of future relative prices of assets. PPPs are likely to change in the future, but the current application of PPPs to wealth assumes that they remain constant over the lifetime of the assets. Further work is needed to assess the impact of this assumption and whether a scenario approach can be designed to understand the implications of this assumption better.

This analysis used AIC-level PPPs as a substitute measure for a total consumption-level PPP. Going forward, ideally, the total consumption PPP would be published and made available for this work.

Lastly, there are several empirical challenges when trying to estimate PPP-based wealth for all countries included in the CWON database. While many countries participate in the ICP and construct PPPs, several do not, especially small countries with limited resources to carry out data collection. The CWON uses a variety of gap-filling approaches for other assets. Designing an appropriate gap-filling method for PPPs would allow the CWON to include the largest possible number of countries in the database.

Conclusion

This chapter demonstrated that valuing the wealth accounts in PPPs is a useful complement to valuing wealth in MERs, helping one understand how wealth and economic well-being vary across countries and aggregate groups. Compared with the MER-based wealth data published in the CWON 2021 core accounts, PPP-based wealth shifts the global distribution of wealth more toward lower-income countries and reduces the apparent disparities among nations. Although the broad aggregate trends yield expected results, some country-level figures provide unexpected results that warrant further examination. While this work provides a proof of concept, methodological issues and data concerns should be addressed in future work, and a more careful look should be taken at the policy implications of valuing wealth in PPPs.

Annex 4A: Total Wealth per Capita in 2018 Using MERs and PPPs

This data annex provides total wealth per capita in 2018 for wealth based on market exchange rates (MERs) and purchasing power parities (PPPs) and the associated price-level ratios for the countries included in the CWON 2021 core accounts (except the República Bolivariana de Venezuela and the Republic of Yemen) in table 4A.1. Data on their aggregate group averages are presented in table 4A.2. The 2017 International Comparison Program report has PPP data for additional countries that are not included in this analysis due to missing wealth data during the 1995–2018 period under study.

TABLE 4A.1 Total Wealth per Capita in 2018, MER-Based and PPP-Based, and the Price-Level Ratio, by Economy

			Total wealth per capita (2018 US$)		Price-level ratio (PPP conversion factor to MER)
Economy	**Income group**	**Region**	**MER-based**	**PPP-based**	
Albania	Upper-middle-income	Europe and Central Asia	64,335	166,119	0.387
Argentina	Upper-middle-income	Latin America and the Caribbean	121,187	262,292	0.462
Armenia	Upper-middle-income	Europe and Central Asia	48,031	159,677	0.301
Australia	High-income: OECD	East Asia and Pacific	827,510	764,827	1.082
Austria	High-income: OECD	Europe and Central Asia	633,748	690,472	0.918
Azerbaijan	Upper-middle-income	Europe and Central Asia	36,315	146,583	0.248
Bahrain	High-income: non-OECD	Middle East and North Africa	211,797	417,964	0.507
Bangladesh	Lower-middle-income	South Asia	19,265	55,669	0.346
Belarus	Upper-middle-income	Europe and Central Asia	77,516	294,580	0.263
Belgium	High-income: OECD	Europe and Central Asia	571,179	623,713	0.916
Belize	Upper-middle-income	Latin America and the Caribbean	38,206	56,907	0.671
Benin	Low-income	Sub-Saharan Africa	20,598	57,889	0.356
Bolivia	Lower-middle-income	Latin America and the Caribbean	41,592	114,821	0.362
Bosnia and Herzegovina	Upper-middle-income	Europe and Central Asia	46,718	116,243	0.402
Botswana	Upper-middle-income	Sub-Saharan Africa	80,602	177,516	0.454

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TABLE 4A.1 Total Wealth per Capita in 2018, MER-Based and PPP-Based, and the Price-Level Ratio, by Economy *(continued)*

Economy	Income group	Region	Total wealth per capita (2018 US$)		Price-level ratio (PPP conversion factor to MER)
			MER-based	PPP-based	
Brazil	Upper-middle-income	Latin America and the Caribbean	117,206	195,232	0.600
Bulgaria	Upper-middle-income	Europe and Central Asia	94,484	253,253	0.373
Burkina Faso	Low-income	Sub-Saharan Africa	8,487	25,363	0.335
Burundi	Low-income	Sub-Saharan Africa	4,594	14,464	0.318
Cambodia	Lower-middle-income	East Asia and Pacific	18,397	54,280	0.339
Cameroon	Lower-middle-income	Sub-Saharan Africa	23,656	61,847	0.383
Canada	High-income: OECD	North America	822,373	893,714	0.920
Central African Republic	Low-income	Sub-Saharan Africa	8,958	18,061	0.496
Chad	Low-income	Sub-Saharan Africa	10,746	26,475	0.406
Chile	High-income: OECD	Latin America and the Caribbean	191,983	292,666	0.656
China	Upper-middle-income	East Asia and Pacific	174,365	286,128	0.609
Colombia	Upper-middle-income	Latin America and the Caribbean	83,065	198,034	0.419
Comoros	Lower-middle-income	Sub-Saharan Africa	18,698	41,754	0.448
Congo, Dem. Rep.	Low-income	Sub-Saharan Africa	9,017	19,801	0.455
Congo, Rep.	Lower-middle-income	Sub-Saharan Africa	44,125	96,202	0.459
Costa Rica	Upper-middle-income	Latin America and the Caribbean	158,035	269,233	0.587
Côte d’Ivoire	Lower-middle-income	Sub-Saharan Africa	19,324	46,759	0.413
Croatia	High-income: non-OECD	Europe and Central Asia	148,289	285,143	0.520
Czech Republic	High-income: OECD	Europe and Central Asia	275,897	518,650	0.532
Denmark	High-income: OECD	Europe and Central Asia	842,148	753,244	1.118
Djibouti	Lower-middle-income	Middle East and North Africa	18,933	35,181	0.538
Dominican Republic	Upper-middle-income	Latin America and the Caribbean	77,101	171,962	0.448
Ecuador	Upper-middle-income	Latin America and the Caribbean	107,013	203,975	0.525

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TABLE 4A.1 Total Wealth per Capita in 2018, MER-Based and PPP-Based, and the Price-Level Ratio, by Economy *(continued)*

Economy	Income group	Region	Total wealth per capita (2018 US$)		Price-level ratio (PPP conversion factor to MER)
			MER-based	PPP-based	
Egypt, Arab Rep.	Lower-middle-income	Middle East and North Africa	18,271	93,317	0.196
El Salvador	Lower-middle-income	Latin America and the Caribbean	35,793	75,423	0.475
Estonia	High-income: OECD	Europe and Central Asia	263,969	420,669	0.627
Eswatini	Lower-middle-income	Sub-Saharan Africa	47,505	107,191	0.443
Ethiopia	Low-income	Sub-Saharan Africa	10,790	32,667	0.330
Finland	High-income: OECD	Europe and Central Asia	614,630	621,362	0.989
France	High-income: OECD	Europe and Central Asia	565,959	652,057	0.868
Gabon	Upper-middle-income	Sub-Saharan Africa	68,567	130,318	0.526
Gambia, The	Low-income	Sub-Saharan Africa	7,853	26,155	0.300
Georgia	Upper-middle-income	Europe and Central Asia	38,510	120,310	0.320
Germany	High-income: OECD	Europe and Central Asia	672,408	806,413	0.834
Ghana	Lower-middle-income	Sub-Saharan Africa	31,861	86,916	0.367
Greece	High-income: OECD	Europe and Central Asia	194,266	295,069	0.658
Guatemala	Upper-middle-income	Latin America and the Caribbean	38,376	71,355	0.538
Guinea	Low-income	Sub-Saharan Africa	8,057	23,132	0.348
Guyana	Upper-middle-income	Latin America and the Caribbean	62,740	125,561	0.500
Haiti	Low-income	Latin America and the Caribbean	11,703	24,390	0.480
Honduras	Lower-middle-income	Latin America and the Caribbean	30,157	68,116	0.443
Hungary	High-income: OECD	Europe and Central Asia	174,761	356,981	0.490
Iceland	High-income: OECD	Europe and Central Asia	987,021	719,302	1.372
India	Lower-middle-income	South Asia	24,102	86,841	0.278
Indonesia	Lower-middle-income	East Asia and Pacific	48,046	144,303	0.333
Iran, Islamic Rep.	Upper-middle-income	Middle East and North Africa	84,546	245,588	0.344
Iraq	Upper-middle-income	Middle East and North Africa	80,875	184,624	0.438
Ireland	High-income: OECD	Europe and Central Asia	472,814	444,029	1.065
Italy	High-income: OECD	Europe and Central Asia	375,541	459,548	0.817

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TABLE 4A.1 Total Wealth per Capita in 2018, MER-Based and PPP-Based, and the Price-Level Ratio, by Economy *(continued)*

Economy	Income group	Region	Total wealth per capita (2018 US$)		Price-level ratio (PPP conversion factor to MER)
			MER-based	PPP-based	
Jamaica	Upper-middle-income	Latin America and the Caribbean	67,740	133,040	0.509
Japan	High-income: OECD	East Asia and Pacific	559,259	617,287	0.906
Jordan	Upper-middle-income	Middle East and North Africa	32,304	74,681	0.433
Kazakhstan	Upper-middle-income	Europe and Central Asia	109,074	341,297	0.320
Kenya	Lower-middle-income	Sub-Saharan Africa	22,055	57,139	0.386
Korea, Rep.	High-income: OECD	East Asia and Pacific	356,619	455,538	0.783
Kuwait	High-income: non-OECD	Middle East and North Africa	748,480	1,228,643	0.609
Kyrgyz Republic	Lower-middle-income	Europe and Central Asia	15,328	65,953	0.232
Lao PDR	Lower-middle-income	East Asia and Pacific	38,079	116,511	0.327
Latvia	High-income: OECD	Europe and Central Asia	233,600	411,743	0.567
Lebanon	Upper-middle-income	Middle East and North Africa	51,673	102,383	0.505
Lesotho	Lower-middle-income	Sub-Saharan Africa	16,712	43,229	0.387
Liberia	Low-income	Sub-Saharan Africa	11,891	25,281	0.470
Lithuania	High-income: OECD	Europe and Central Asia	191,787	385,759	0.497
Luxembourg	High-income: OECD	Europe and Central Asia	898,547	793,984	1.132
Madagascar	Low-income	Sub-Saharan Africa	8,375	29,823	0.281
Malawi	Low-income	Sub-Saharan Africa	7,876	23,487	0.335
Malaysia	Upper-middle-income	East Asia and Pacific	167,365	420,520	0.398
Maldives	Upper-middle-income	South Asia	50,795	89,676	0.566
Mali	Low-income	Sub-Saharan Africa	10,061	29,913	0.336
Malta	High-income: non-OECD	Middle East and North Africa	296,649	435,943	0.680
Mauritania	Lower-middle-income	Sub-Saharan Africa	18,501	58,252	0.318
Mauritius	Upper-middle-income	Sub-Saharan Africa	99,108	200,086	0.495
Mexico	Upper-middle-income	Latin America and the Caribbean	98,664	210,942	0.468
Moldova	Lower-middle-income	Europe and Central Asia	31,608	100,767	0.314
Mongolia	Lower-middle-income	East Asia and Pacific	46,734	146,239	0.320
Morocco	Lower-middle-income	Middle East and North Africa	30,731	70,857	0.434

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TABLE 4A.1 Total Wealth per Capita in 2018, MER-Based and PPP-Based, and the Price-Level Ratio, by Economy *(continued)*

Economy	Income group	Region	Total wealth per capita (2018 US$)		Price-level ratio (PPP conversion factor to MER)
			MER-based	PPP-based	
Mozambique	Low-income	Sub-Saharan Africa	6,505	18,480	0.352
Namibia	Upper-middle-income	Sub-Saharan Africa	66,120	131,697	0.502
Nepal	Low-income	South Asia	15,280	54,941	0.278
Netherlands	High-income: OECD	Europe and Central Asia	690,432	749,906	0.921
Nicaragua	Lower-middle-income	Latin America and the Caribbean	26,024	77,402	0.336
Niger	Low-income	Sub-Saharan Africa	7,507	17,864	0.420
Nigeria	Lower-middle-income	Sub-Saharan Africa	28,621	81,347	0.352
North Macedonia	Upper-middle-income	Europe and Central Asia	54,085	153,348	0.353
Norway	High-income: OECD	Europe and Central Asia	1,185,533	980,739	1.209
Oman	High-income: non-OECD	Middle East and North Africa	165,669	312,064	0.531
Pakistan	Lower-middle-income	South Asia	16,380	55,569	0.295
Panama	High-income: non-OECD	Latin America and the Caribbean	129,946	282,994	0.459
Papua New Guinea	Lower-middle-income	East Asia and Pacific	33,011	53,075	0.622
Paraguay	Upper-middle-income	Latin America and the Caribbean	81,869	197,387	0.415
Peru	Upper-middle-income	Latin America and the Caribbean	79,464	151,570	0.524
Philippines	Lower-middle-income	East Asia and Pacific	35,135	97,862	0.359
Poland	High-income: OECD	Europe and Central Asia	139,208	315,093	0.442
Portugal	High-income: OECD	Europe and Central Asia	251,045	372,442	0.674
Qatar	High-income: non-OECD	Middle East and North Africa	902,740	1,222,565	0.738
Romania	Upper-middle-income	Europe and Central Asia	118,397	297,280	0.398
Russian Federation	Upper-middle-income	Europe and Central Asia	173,394	501,565	0.346
Rwanda	Low-income	Sub-Saharan Africa	11,314	36,768	0.308
Saudi Arabia	High-income: non-OECD	Middle East and North Africa	324,194	726,435	0.446
Senegal	Lower-middle-income	Sub-Saharan Africa	15,217	38,798	0.392

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TABLE 4A.1 Total Wealth per Capita in 2018, MER-Based and PPP-Based, and the Price-Level Ratio, by Economy *(continued)*

Economy	Income group	Region	Total wealth per capita (2018 US$)		Price-level ratio (PPP conversion factor to MER)
			MER-based	PPP-based	
Sierra Leone	Low-income	Sub-Saharan Africa	9,171	32,695	0.280
Singapore	High-income: non-OECD	East Asia and Pacific	817,846	1,092,628	0.749
Slovak Republic	High-income: OECD	Europe and Central Asia	200,594	330,279	0.607
Slovenia	High-income: OECD	Europe and Central Asia	331,087	489,111	0.677
Solomon Islands	Lower-middle-income	East Asia and Pacific	38,937	44,423	0.877
South Africa	Upper-middle-income	Sub-Saharan Africa	64,366	135,416	0.475
Spain	High-income: OECD	Europe and Central Asia	328,253	431,793	0.760
Sri Lanka	Upper-middle-income	South Asia	29,972	102,480	0.292
Suriname	Upper-middle-income	Latin America and the Caribbean	92,740	256,841	0.361
Sweden	High-income: OECD	Europe and Central Asia	748,540	713,695	1.049
Switzerland	High-income: OECD	Europe and Central Asia	1,280,371	967,508	1.323
Tajikistan	Low-income	Europe and Central Asia	24,668	107,095	0.230
Tanzania	Low-income	Sub-Saharan Africa	15,378	47,514	0.324
Thailand	Upper-middle-income	East Asia and Pacific	78,216	207,437	0.377
Togo	Low-income	Sub-Saharan Africa	13,612	33,897	0.402
Trinidad and Tobago	High-income: non-OECD	Latin America and the Caribbean	117,979	202,816	0.582
Tunisia	Lower-middle-income	Middle East and North Africa	28,858	104,367	0.277
Turkey	Upper-middle-income	Europe and Central Asia	43,071	138,397	0.311
Turkmenistan	Upper-middle-income	Europe and Central Asia	102,707	224,207	0.458
Uganda	Low-income	Sub-Saharan Africa	10,407	34,364	0.303
Ukraine	Lower-middle-income	Europe and Central Asia	55,272	247,367	0.223
United Arab Emirates	High-income: non-OECD	Middle East and North Africa	614,419	827,760	0.742
United Kingdom	High-income: OECD	Europe and Central Asia	493,795	518,827	0.952
United States	High-income: OECD	North America	872,400	872,400	1.000
Uruguay	High-income: non-OECD	Latin America and the Caribbean	222,279	283,251	0.785
Vietnam	Lower-middle-income	East Asia and Pacific	34,084	107,716	0.316

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TABLE 4A.1 Total Wealth per Capita in 2018, MER-Based and PPP-Based, and the Price-Level Ratio, by Economy *(continued)*

Economy	Income group	Region	Total wealth per capita (2018 US$)		Price-level ratio (PPP conversion factor to MER)
			MER-based	PPP-based	
West Bank and Gaza	Lower-middle-income	Middle East and North Africa	26,451	51,420	0.514
Zambia	Lower-middle-income	Sub-Saharan Africa	28,154	71,812	0.392
Zimbabwe	Lower-middle-income	Sub-Saharan Africa	23,319	50,528	0.462

Source: World Bank staff calculations.
Note: MER = market exchange rate; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity.

TABLE 4A.2 Total Wealth per Capita in 2018, MER-Based and PPP-Based, and the Price-Level Ratio, by Aggregate Group

Aggregate group	Total wealth per capita (2018 US$)		Price-level-ratio (PPP conversion factor to MER)
	MER-based	PPP-based	
Income group			
Low-income	10,781	32,072	0.336
Lower-middle-income	27,108	89,497	0.303
Upper-middle-income	140,719	264,460	0.532
High-income: non-OECD	400,891	699,548	0.573
High-income: OECD	621,278	673,663	0.922
Region			
East Asia and Pacific	176,125	278,549	0.632
Europe and Central Asia	322,739	461,130	0.700
Latin America and the Caribbean	101,430	192,979	0.526
Middle East and North Africa	109,352	246,311	0.444
North America	867,304	874,572	0.992
South Asia	22,680	79,961	0.284
Sub-Saharan Africa	20,473	53,720	0.381
World	**160,437**	**242,516**	**0.662**

Source: World Bank staff calculations.
Note: MER = market exchange rate; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity.

Note

1. The baseline MER-based wealth figures for comparison to PPPs are the same as the core accounts published in CWON 2021, except for the exclusion of the República Bolivariana de Venezuela and the Republic of Yemen due to lack of data.

PART II

Measuring Comprehensive Wealth: New Work on Natural Capital and Human Capital

5

Land Assets, Climate Change, and Degradation Impacts

Glenn-Marie Lange and Diego Herrera

Main Messages

- Global wealth in land assets (cropland, pastureland, protected areas, forest timber, and ecosystem services) increased by 43 percent, from US$24 trillion to US$35 trillion, between 1995 and 2018. The increase was driven mainly by growth in cropland wealth, from US$11 trillion to US$15 trillion, and forest ecosystem services wealth (water services, recreation services, and nonwood forest products), from US$5 trillion to US$7.5 trillion.
- Low-income countries as a group show a decline in wealth per capita in all land assets. Countries in Sub-Saharan Africa as a group also show a decline in wealth per capita in all land assets.
- Global wealth in agricultural lands (cropland and pastureland) increased between 1995 and 2018. Scenarios show that this trend could be reversed in the future because of changes in temperature, precipitation, and land degradation, which combined have a negative impact on predicted crop yields.
- Forest ecosystem services wealth increased globally between 1995 and 2018 in absolute and per capita terms. An analysis of recreation services shows that some countries in South and Central America, Sub-Saharan Africa, and Southeast Asia have experienced losses because of forest degradation, but others, especially in Europe and Asia outside Southeast Asia, have increased recreation services as a product of forest cover gains.

Introduction

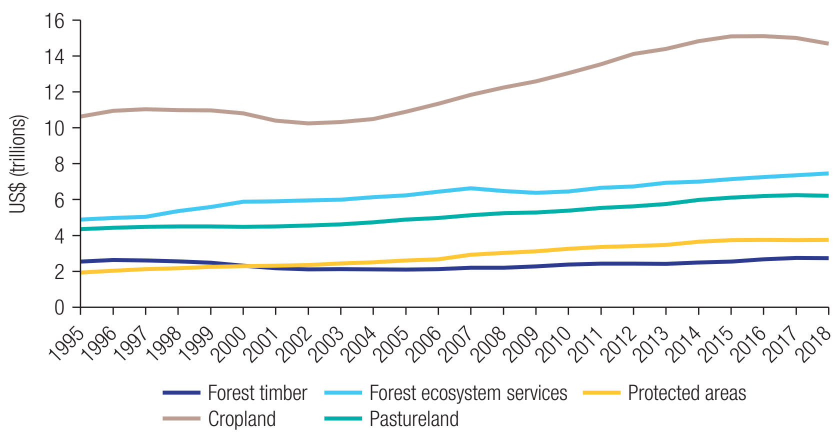
This chapter presents the main trends in land assets, including agricultural land (cropland and pastureland), forests (timber and ecosystem services), and protected areas. This asset class is critical because land comprehensively is the only asset that, if managed sustainably, is renewable. Although land's share of total wealth has been declining, its assorted assets are still a critical component of total wealth in low- and middle-income countries. The chapter begins with a discussion of the growth in land assets between 1995 and 2018, across regions and income groups, followed by a section on trade-offs between land assets in low- and middle-income countries. The next two sections discuss how the largest land assets could be affected by climate change and degradation. The chapter presents an assessment of cropland wealth under climate change scenarios and discusses the impacts of forest degradation on forest ecosystem services. Mangrove ecosystems, located at the sea-land interface, are discussed in detail in chapter 6 as part of blue natural capital.[1]

Land Assets: Global and Regional Trends, 1995–2018

At the global level, total wealth in the land assets increased by 43 percent, from US$24 trillion to US$35 trillion, between 1995 and 2018. This was driven mainly by growth in cropland wealth, from US$11 trillion to US$15 trillion, and forest ecosystem services wealth, from US$5 trillion to US$7.5 trillion (figure 5.1). Wealth per capita for land assets also increased globally, except forest timber wealth, which declined roughly 20 percent (table 5.1).

Across regions, there were significant differences in the growth of per capita wealth during 1995–2018 (figure 5.2). In Sub-Saharan Africa, all

FIGURE 5.1 Total Global Wealth in the Land Sector, 1995–2018



Source: World Bank staff calculations.

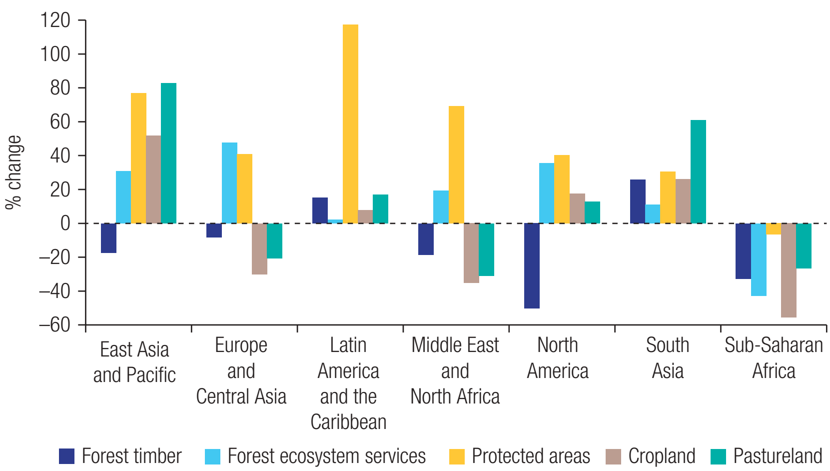
TABLE 5.1 Land Sector Wealth per Capita, by Asset, 1995–2018

constant 2018 US$

Asset	1995	2000	2005	2010	2015	2018
Forest timber	469	398	339	362	367	379
Forest ecosystem services	899	1,012	1,008	983	1,027	1,037
Protected areas	355	393	422	495	538	521
Cropland	1,958	1,860	1,763	1,987	2,169	2,042
Pastureland	803	770	789	821	878	864

Source: World Bank staff calculations.

FIGURE 5.2 Change in Wealth per Capita, by Land Asset and Region, 1995–2018



Source: World Bank staff calculations.

land assets show a decrease. In this region most land assets grew in total wealth (except cropland) but not fast enough to compensate for the very high population growth. Cropland and pastureland per capita wealth increased in East Asia and Pacific, Latin America and the Caribbean, North America, and South Asia, but they declined in Europe and Central Asia and the Middle East and North Africa. Protected area wealth per capita increased in all regions other than Sub-Saharan Africa, with the largest increase in Latin America and the Caribbean. Forest ecosystem services wealth per capita increased in all regions other than Sub-Saharan Africa, while forest timber wealth per capita declined in all regions but Latin America and the Caribbean and South Asia.

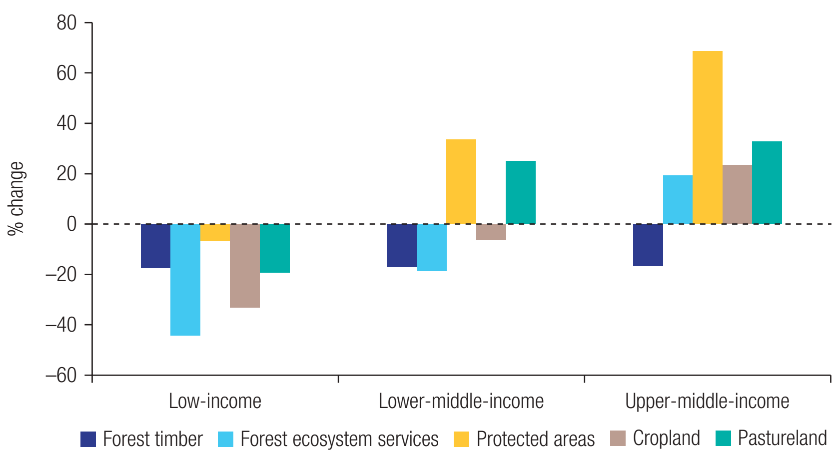
For *The Changing Wealth of Nations* (CWON) *2021*, Gerber et al. (2021) generated new country-specific crop yield growth rates estimated at the grid-cell level, accounting for the impacts of climate change as well as degradation, which translates into lower but more realistic crop yield growth rates. This is an improvement over previous editions of CWON, which assumed fixed crop production growth rates. Cropland wealth values presented in this section already include the effect of climate change on crop yields based on the Intergovernmental Panel on Climate Change's Representative Concentration Pathway (RCP) 4.5, assumed as the baseline or business-as-usual (BAU) climate scenario.

Trade-Offs across Land Assets in Low- and Middle-Income Countries

Land assets make up an important share of total wealth in low- and middle-income countries. The percentage share of land assets in total wealth is 16 percent on average for these countries, with some showing shares above 40 percent, as in Guinea (45 percent) and Mali (43 percent). But low-income countries experienced a decline in wealth per capita in all land assets between 1995 and 2018, while lower- and upper-middle-income countries show some assets declining and others increasing over the same period (figure 5.3).

In terms of value both per square kilometer and per capita, low- and middle-income countries as a group appear to be trading off some renewable assets for others. While forest (timber plus ecosystem services) wealth per capita decreased by 8 percent between 1995 and 2018, driven by population growth (population dilution effect) and loss in the area of forest, agricultural land (cropland plus pastureland) wealth per capita increased by 9 percent because of area expansion and increasing value per

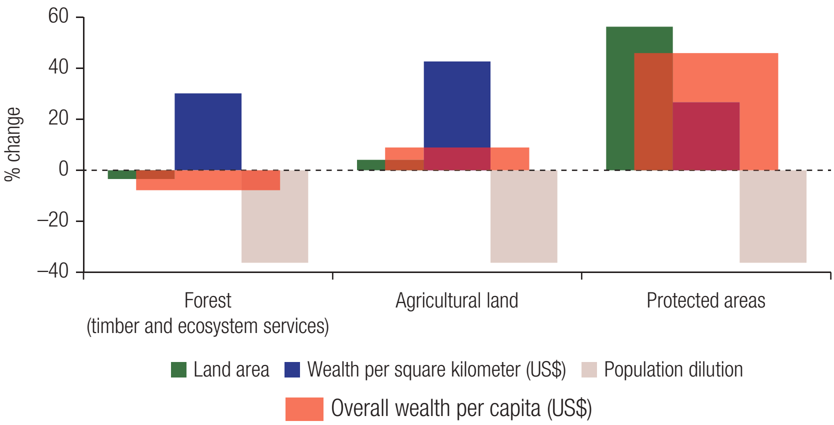
FIGURE 5.3 Change in Wealth per Capita in Low- and Middle-Income Countries, by Land Asset, 1995–2018



Source: World Bank staff calculations.

square kilometer (figure 5.4). The area in agriculture increased by 4 percent between 1995 and 2018 in low- and middle-income countries. Forest land area declined by 4 percent overall, because of conversion to agriculture and other land uses, notably in Sub-Saharan Africa (−13 percent) and Latin America (−10 percent) (table 5.2). Protected areas show a rapid increase in area and wealth per square kilometer (using the opportunity cost of land as a lower-bound approach to valuation).

FIGURE 5.4 Forests, Agricultural Land, and Protected Areas: Change in Land Area, Wealth per Square Kilometer, Population Dilution Effect, and Overall Wealth per Capita in Low- and Middle-Income Countries, 1995–2018



Source: World Bank staff calculations.

TABLE 5.2 Change in Forest, Agricultural, and Protected Land Areas in Low- and Middle-Income Countries, by Region, 1995–2018

	Forest area (1,000 sq. km.)		%	Agricultural land area (1,000 sq. km.)		%	Protected areas (1,000 sq. km.)		%
Region	**1995**	**2018**	**change**	**1995**	**2018**	**change**	**1995**	**2018**	**change**
East Asia and Pacific	4,082	4,409	7	7,378	7,676	4	1,944	2,273	14
Europe and Central Asia	8,631	8,734	1	6,117	6,059	−1	1,463	1,909	23
Latin America and the Caribbean	9,768	8,908	−10	6,646	7,221	8	2,171	4,514	52
Middle East and North Africa	166	191	13	1,440	1,266	−14	124	434	71
South Asia	751	797	6	2,329	2,326	0	259	331	22
Sub-Saharan Africa	5,758	5,112	−13	7,571	8,210	8	2,363	3,542	33
All low- and middle-income countries	29,156	28,151	−4	31,481	32,759	4	8,324	13,003	36

Sources: World Bank staff calculations based on data from the Food and Agriculture Organization for forest land and agricultural land and on data from the World Development Indicators for protected areas.
Note: sq. km. = square kilometers.

For low-income countries that rely significantly on land assets for wealth creation, a decline in wealth per capita in all categories of land assets, as well as a trade-off between forests and agricultural wealth if the latter declines under climate change, are cases of special concern, given the increased vulnerability and challenges for sustainable management of assets. Take the example of Niger, a country that experienced a decline in forest timber, ecosystem services, and pastureland wealth per capita (−61, −66, and −23 percent, respectively) and an increase in cropland (71 percent); the latter has been declining since 2015, and climate change impacts could have a negative impact on future crop yields, as described in the next section.

Cropland Wealth and Climate Change Scenarios

The literature on the impact of climate change on crop yields consistently shows negative impacts of temperature increase on crop yields at the global scale. One finds similar impacts at the country and site scales but with significant uncertainty and variation across crops (Mbow et al. 2019). Iizumi et al. (2017) show that the projected global mean yields of maize and soybean at the end of this century decrease monotonically with warming, whereas those of rice and wheat increase with warming but level off at about 3 degrees Celsius. Impacts on crops grown in the tropics are projected to be more negative than those in middle to high latitudes (Levis et al. 2018). For the Middle East and North Africa, Reyer et al. (2017) found a significant correlation between crop-yield decrease and temperature increase. A review of recent literature found that projected yield loss for West Africa depends on the degree of wetter or drier conditions and elevated carbon dioxide concentrations (Sultan and Gaetani 2016).

Gerber et al. (2021) base future crop production on projections of the yields of 10 major crops: barley, cassava, maize, oil palm, rapeseed, rice, sorghum, soybeans, sugarcane, and wheat. Together these make up 83 percent of the calories produced on cropland, assuming the production area is held constant. Gerber et al. determine future yields by extrapolating current yield growth and allowing them to be affected by climate change. Extrapolated yields are not allowed to exceed a yield ceiling, nor to undergo unbounded growth. The yield ceiling is determined with a "frontier" approach using a quantile regression model. Land degradation (driven by salinization, unsustainable irrigation, and erosion) is treated as a local phenomenon and hence reflected in national-level yield trends. The calculated yield ceiling is locally discounted to account for land degradation. Climate change impacts on the extrapolated yield ceiling are estimated consistent with accounting for climate change impacts on observed yields.

Yield and harvested area data for major crops come from a data set recently developed by Ray et al. (2019). The data set was constructed using crop statistics from 1974 to 2012 across 20,000 political units globally. Value-of-production data come from the Food and Agriculture

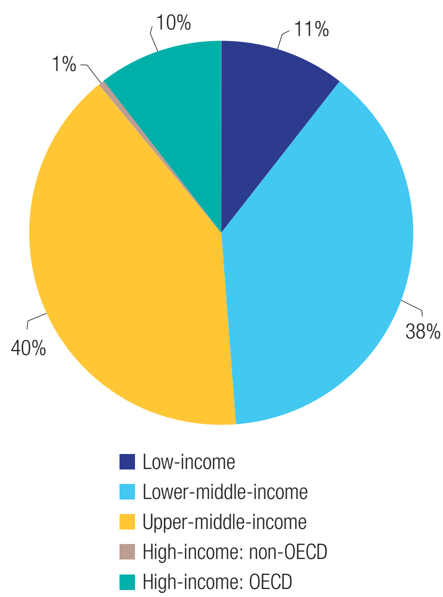
Organization (FAO), and biophysical data come from various sources. Future yield scenarios incorporate the effect of future climate predicted by RCPs, using RCP 4.5 as the BAU scenario and comparing it to RCP 7.0 as a high-emissions scenario and RCP 2.6 as a low-emissions scenario. The full methodology and data sources are described in Gerber et al. (2021).

While climate change can have either a negative or positive effect on crop yields, depending on the type of crop and region, at the global level one observes a negative impact on yields and cropland wealth in the high emissions scenario relative to the BAU and a positive impact in the low emissions scenario relative to the BAU. Global losses in cropland wealth under a high emissions scenario relative to BAU occur mainly in low- and middle-income countries, particularly in middle-income countries. Notably, the share of global wealth losses is similar between low-income and high-income countries but slightly higher for low-income countries (figure 5.5).

Figure 5.6 shows climate impacts on 2018 cropland wealth for the 10 most affected countries, specifically, the loss in total wealth between the high-emissions and BAU scenarios. Asian countries are the most affected, with China, India, Indonesia, and Malaysia at the top of the list.

FIGURE 5.5 Climate Change Impact on Cropland Wealth, by Income Group, 2018: High-Emissions Scenario (RCP 7.0) Relative to Business-as-Usual Scenario (RCP 4.5)

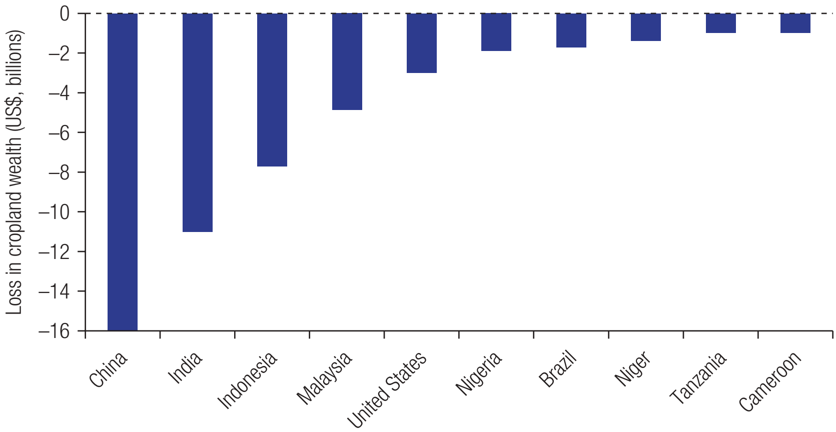
share of global losses



Source: World Bank staff calculations.

Note: Middle East and North Africa results are based on global average crop-yield growth rates because of outliers in country-level data. RCP = Representative Concentration Pathway.

FIGURE 5.6 Climate Change Impact on Cropland Wealth: High-Emissions Scenario (RCP 7.0) Relative to Business-as-Usual Scenario (RCP 4.5) in the 10 Most Affected Countries



Source: World Bank staff calculations.
Note: RCP = Representative Concentration Pathway.

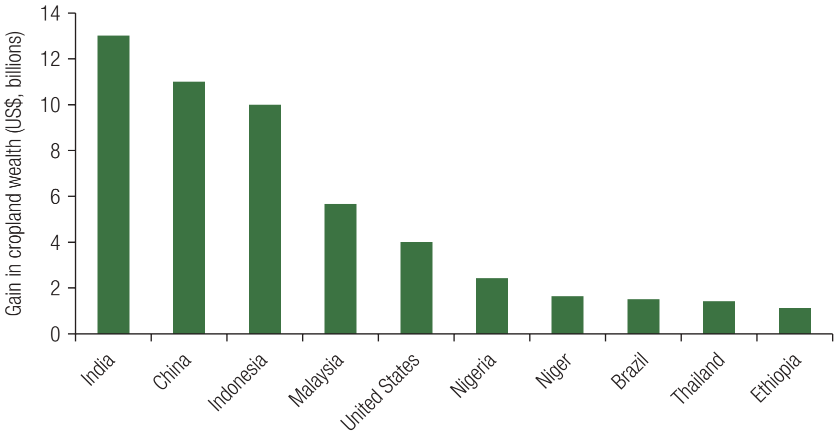
The United States is the only high-income country among the 10 most affected countries, followed by middle-income and low-income countries in Africa (Nigeria, Niger, Tanzania, and Cameroon) and South America (Brazil). Figure 5.7 shows the impacts of the low-emissions scenario relative to the BAU scenario. In this case, the differences between scenarios show the gains in cropland wealth for the most affected countries. India would benefit the most from a low-emissions scenario compared with BAU. The rest of the list is similar to the list in figure 5.6, but Thailand and Ethiopia replace Tanzania and Cameroon.

It is important to note that these results are expected to be conservative, because the model does not include a variety of mechanisms for the impacts of climate change. One example is the future change in daily precipitation maxima, which could lead to greater impacts on crop yields. Increased atmospheric carbon dioxide and estimates of future crop mix and harvested area also affect the results. There are other sources of uncertainty in the model stemming from crop-yield modeling. As previous studies have shown, climate change impacts on agriculture combining climate, crop, and economic models have shown substantial variation resulting from differences in models, scenarios, and data (Nelson et al. 2014).

Forest Ecosystem Services Trends and the Impacts of Degradation

Forests contribute to natural capital through timber and ecosystem services. In this edition of the CWON, forest ecosystem services include

FIGURE 5.7 Climate Change Impact on Cropland Wealth: Low-Emissions Scenario (RCP 2.6) Relative to Business-as-Usual Scenario (RCP 4.5) in the 10 Most Affected Countries



Source: World Bank staff calculations.
Note: RCP = Representative Concentration Pathway.

three categories. The first encompasses recreation, hunting, and fishing (referred to as "recreation services"). The second covers the more far-ranging watershed protection, including the benefits of forests for water quality and quantity, often in the context of controlling water flow and pollution from erosion and other sources, enabling hydropower, avoiding disasters, or the impact on crop yields by controlling weather ("water services"). Third are nonwood forest products.

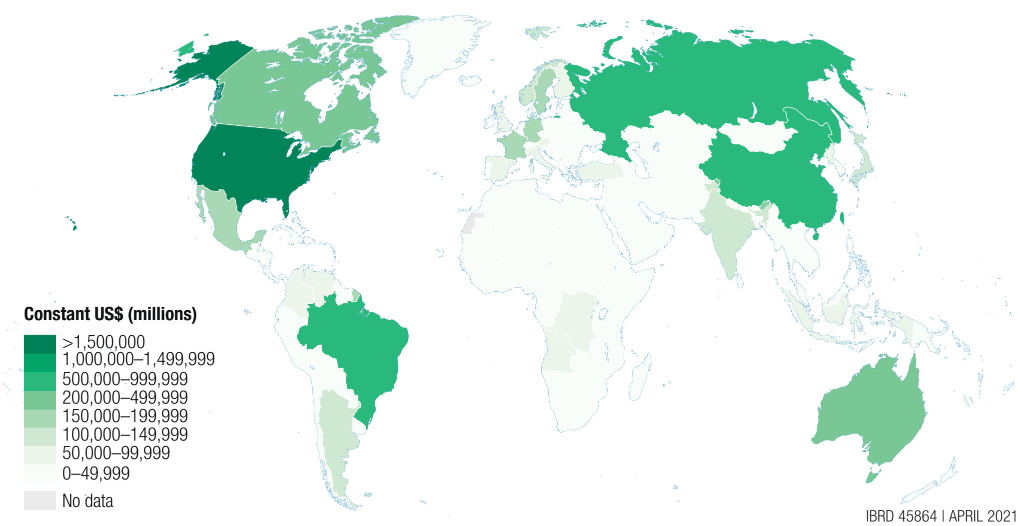
Per hectare estimates of forest ecosystem services wealth for CWON 2021 were developed by Siikamäki et al. (2021), extending the analysis of Siikamäki, Santiago-Ávila, and Vail (2015), which was used in CWON 2018. The new work updates and augments the studies in the valuation database by incorporating newly available studies, complementing the previous metaregression analyses with machine-learning approaches to predict the economic value of forest ecosystem services, and formulating an operational method for identifying forest degradation based on remotely sensed data that can be applied globally at the grid cell level. These data are used to estimate how the economic value of different forest ecosystem services is affected by forest degradation. Using the results of this analysis, forest degradation is included as a determinant of the economic value of forest ecosystem services.

The metaregression estimation data set in Siikamäki et al. (2021) includes values from 53 countries on five continents. The most represented regions are Europe, North America, South America, and Southeast Asia. All the continents with forests and all the different forest biomes—humid tropics, dry tropics, temperate, and boreal—are represented. Socioeconomic, biophysical, climate, ecological extent, and ecological condition variables were constructed to estimate the global spatially explicit predictions of the different forest ecosystem services. The total value of forest ecosystem services per country is computed by multiplying the combined per hectare value of recreation, nonwood forest products, and water services by the total forest area per country, measured using official international forest statistics from FAO. Total forest ecosystem services wealth by country is shown in map 5.1. The greatest concentration of ecosystem services wealth is in Europe, East Asia and Pacific, North America, and South America. The Middle East and North Africa and Sub-Saharan Africa have the lowest total forest ecosystem services wealth.

Between 1995 and 2018, the percentage change in forest ecosystem services wealth varied across types of ecosystem services and regions (figure 5.8). Water services increased in all regions, but the largest increases were in South Asia (240 percent) and East Asia and Pacific (140 percent). Recreation services also increased in all regions, with the largest percentage changes in South Asia (432 percent), Latin America and the Caribbean (380 percent), and the Middle East and North Africa (381 percent). In contrast, nonwood forest products decreased in most regions (with only a very small increase in South Asia), with the largest percentage declines in East Asia and Pacific (−28 percent) and the Middle East and North Africa (−13 percent).

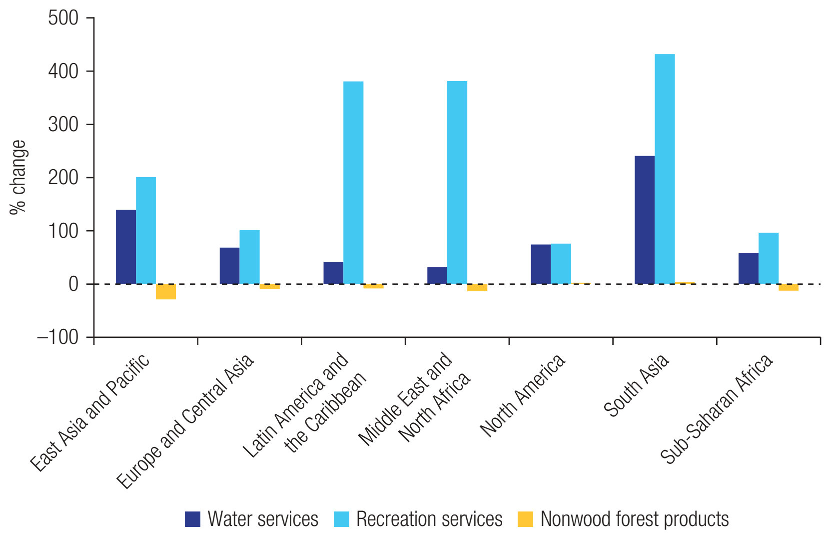
Global forest ecosystem services wealth estimates are conservative given that they include only three categories of ecosystem services: nonwood forest products, water services, and recreation services. Critical services such as habitat and species protection, cultural and/or existence

MAP 5.1 Global Forest Ecosystem Services Wealth, 2018



Source: World Bank.

FIGURE 5.8 Change in Forest Ecosystem Services Wealth, by Type of Services and Region, 1995–2018



Source: World Bank staff calculations.

values, or landscape aesthetics (also analyzed by Siikamäki et al. 2021) are not included in the CWON accounts given the lack of proper market equivalent values consistent with the wealth accounting methodologies. A different approach is needed to account for the impacts of biodiversity loss on development outcomes, given that these services are largely unpriced by markets (World Bank 2021). Carbon retention is another key ecosystem service not considered here. As the System of Environmental-Economic Accounting wealth accounting methodologies expand to include carbon retention (see annex 1A, in chapter 1, for more details), this service is likely to become an important component of land and forest wealth, in particular for low- and middle-income countries. This has been captured in localized in-depth assessments, for example, in an analysis of sediment retention services in Nepal presented in box 5.1.

Forest degradation—the reduction of the capacity of a forest to provide goods and services (FAO 2012)—may influence the flow of benefits that forests generate in the form of ecosystem services. Yet studies of forest ecosystem services seldom estimate the effect of forest degradation on the value of these services. Valuation that does not consider forest condition is likely to overestimate the value of (1) forests on the edges of forest patches (because of their susceptibility to fire); (2) forests fragmented by roads and other infrastructure (because of their impact on soil

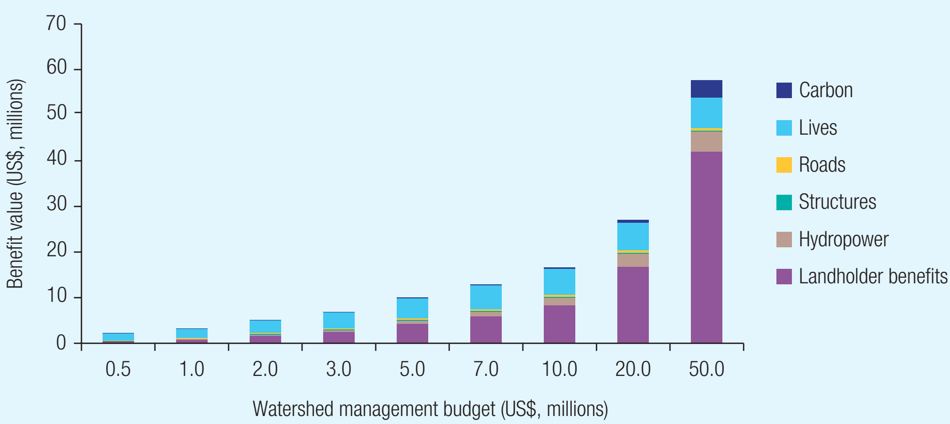
BOX 5.1 Case Study: Valuing Sediment Retention Services in Nepal

Minimizing the loss of soil and downstream sedimentation is one of the most visible and immediate benefits of watershed management. The positive impact can be felt across many sectors of the economy, including agriculture, hydropower, and water. These practices also help to regulate water flows, help stabilize soils, maintain soil fertility, improve soil water-holding capacity, regulate water quality in downstream rivers, mitigate shallow to medium-depth landslides, and sequester carbon. They generate other on-site benefits to landholders such as fuelwood and fodder for livestock.

Using the Kali Gandaki watershed in Nepal as the study site, the World Bank (2019) applies a systematic approach to assess where, in what quantity, and through what processes sediment is being generated in the Kali Gandaki watershed; identify plausible interventions through investing in green infrastructure approaches for watershed management; and evaluate their impacts.

The results for watershed management portfolios ranging from US$500,000 to US$50 million show that such programs can have a significant, positive impact across many sectors. The benefits are driven largely by local benefits and the value of avoided lives lost in landslides, with the next highest beneficiary being downstream hydropower (figure B5.1.1). At the US$500,000 budget level, each US$1 invested yields US$4.38 in benefits, but this ratio drops as budgets are increased. However, even with an investment of US$50 million, the program's benefit-cost ratio is still greater than one, even without considering the carbon sequestration benefit.

FIGURE B5.1.1 Values of the Sediment Retention Ecosystem Service of Watersheds, Total and by Sector



Source: World Bank 2019.

erosion, water quality, and landscape connectivity); (3) monoculture tree plantations (particularly in water-scarce regions, because of their impact on water balance and loss of nonwood forest products and recreation); (4) heavily logged forests (because of their impact on water yield and water quality); and (5) degraded riparian forests that buffer streams (because of their impact on water quality and possibly fishing). Conversely, valuation that does not consider forest condition is likely to underestimate the value of forests in intact forests (which likely overlap with species-rich forest and forest with low human impact), forests that provide landscape connectivity to maintain the value of charismatic species for recreation and wildlife tourism, and forested indigenous and community lands that provide nonwood forest products to support livelihoods.

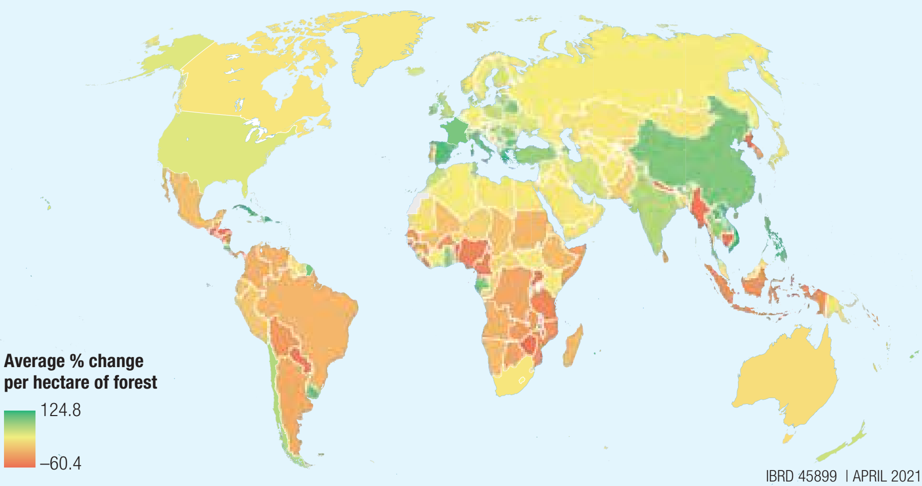
DeFries, Osuri, and Malhi (2021) propose a typology of forest degradation that includes three major types: (1) loss of biomass and structure, (2) impoverishment of species composition, and (3) fragmentation of forests. Two main approaches exist to measure these three types of forest degradation. The first approach involves measuring degradation directly by examining data on productivity, biomass, or biodiversity over time. Any negative trends during the period of interest indicate degradation. The second approach involves observing the drivers of degradation, such as human pressures on forests, including the development of roads or changes in population density, and using them to proxy forest degradation.

Siikamäki et al. (2021) explore a series of metrics for the two approaches and examine the role of forest degradation using a spatially explicit predictive model to forecast the values of four nonwood forest ecosystem services. The authors identify variables that are applicable for global predictions and assessment of the marginal effect of forest degradation. The variables include the normalized difference vegetation index, forest cover change, number of threatened species, and percentage of threatened species. Data on the impoverishment of species composition and forest fragmentation are statistically significant predictors of the value of recreation ecosystem services, per hectare of forest. Species impoverishment is measured as the percentage of threatened species of all species at the site, subject to valuation. Forest fragmentation is measured as the change in the percentage of forest cover between 1992 and 2018. Keeping everything else constant, both variables drive down the value of the recreation services supported by a hectare of forest. Siikamäki et al. (2021) used the model to back-cast how the change in forest cover that took place between 1992 and 2018 affected the value of recreation ecosystem services (box 5.2).

BOX 5.2 Forest Degradation and the Value of Recreation Services

Siikamäki et al. (2021) find that the global value of forest recreation ecosystem services in 2018 was on average US$116.8 per hectare. As a combined result of forest losses and gains, the net change in the value of recreation services from forests would be 1.75 percent lower than in the absence of any change in forest cover between 1992 and 2018. But considerable heterogeneity exists between different countries in the effect of forest degradation on the value of recreation ecosystem services. Eighty-seven countries, especially in South and Central America, Sub-Saharan Africa, and Southeast Asia, experienced losses in the value of recreation services (map B5.2.1). Other regions have gained as a product of forest cover gains, especially Europe and much of Asia outside Southeast Asia.

MAP B5.2.1 Net Change in the Value of Forest Recreation Ecosystem Services Because of Change in Forest Cover between 1992 and 2018



Source: World Bank, based on data from Siikamäki et al. 2021.

Conclusion

Although total global wealth per capita in land assets (the sum of cropland, pastureland, protected areas, forest timber, and ecosystem services) has increased, there are significant differences across regions and income groups, and there are trade-offs in assets in low- and middle-income countries. Low-income countries as a group have experienced a decline in all land assets. Sub-Saharan Africa shows a similar trend.

Land assets continue to be a critical component of wealth in low- and middle-income countries. While this chapter considered only a subset of forest ecosystem services, recognition of their importance for global services like carbon retention and biodiversity protection highlights the need to develop robust policy mechanisms that generate income for countries that provide these services and accounting methodologies to add these monetary values or complementary physical metrics to the wealth accounts.

This edition of the CWON incorporates several methodological improvements into the measurement of wealth in the land sector and provides for the first time an assessment of climate change and degradation impacts on cropland and forest ecosystem services wealth, the two largest land assets. Inclusion of these factors (even with conservative impact estimates) shows the importance of sustainable management of land assets for low- and middle-income nations as degradation impacts have already occurred and future climate change and degradation could be obstacles to future development.

Besides including additional ecosystem services, future editions of the CWON could take a closer look at the interactions between forest accounts and other assets, in particular, agricultural assets and human capital. Novel analysis demonstrated the importance of studying the dynamic relationship between economic systems and forest ecosystem services, assessing how economic growth affects ecosystem services delivery and feedbacks into growth, with important implications for the agriculture sector (Johnson et al. 2021). The COVID-19 crisis highlighted the importance of better understanding the connections among forest condition, biodiversity, and human health. It is estimated that 60 percent of all infectious diseases in humans and 75 percent of all emerging infectious diseases are zoonotic, that is, they originate from the transfer of pathogens from animals to humans (UNEP 2016). Forest clearing for the expansion of the agricultural frontier and human settlement plays a key role in the emergence of zoonoses. Large-scale deforestation, along with land degradation, illegal trade in wildlife, and climate change, could lead to an increase in the occurrence of diseases like COVID-19 and its devastating economic consequences (Bloomfield, McIntosh, and Lambin 2020; Gibb et al. 2020).

Note

1. The "blue" economy is the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems. It encompasses economic sectors such as fisheries, maritime transport, tourism, and others dependent on ocean ecosystems (World Bank and UN 2017). In this report "blue natural capital" refers only to mangroves and fisheries.

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6

Blue Natural Capital: Mangroves and Fisheries

Glenn-Marie Lange, Michael W. Beck, Vicky W. Y. Lam, Pelayo Menéndez, and U. Rashid Sumaila

Main Messages

- Overall blue natural capital based on mangroves and marine capture fisheries was less than 1 percent of global wealth in 2018, but these resources are a critical component of wealth for some countries.[1]
- As a share of total wealth, blue natural capital fell by half from 1995 to 2018. While the value of fisheries fell, largely because of overfishing, the value of mangrove flood protection grew, largely because of the substantial increase in coastal flood risk.
- With fewer healthy fish stocks and expanding fishing capacity, fishing costs rose and financial rents plummeted, in many cases to close to zero. If financial rents are further adjusted for capacity-enhancing subsidies, only 21 of 110 countries had fisheries that generated positive rents and contributed to national wealth in 2018. Scenario analysis indicates increased vulnerability of fisheries to the potential impacts of climate change, especially in Sub-Saharan Africa.
- Mangroves grew in value, even as their coverage fell by 4 percent, because coastal development increased the population and value of assets that mangroves protect from flooding. The future value of mangroves through 2050 is likely to be driven strongly by changes in coastal development. After 2050, climate change will likely play a more dominant role.
- With management reform, fisheries are capable of generating substantial rents without the subsidies that act as a fiscal drag on the economy.

Introduction

The critical economic, social, and cultural roles played by ocean ecosystems are widely recognized (Duarte et al. 2020), yet these ecosystems are deteriorating worldwide (Sumaila et al. 2012) and with them, the capacity to support human well-being (Hicks et al. 2019). The threats range from climate change (Lam et al. 2020) and overfishing (Srinivasan et al. 2010) to land-based threats like plastic waste (Abbott and Sumaila 2019) and poorly planned coastal development. Poor communities are especially vulnerable because of their high dependence on healthy oceans for food and livelihoods (Stuchtey et al. 2020). Part of the solutions for restoring ocean ecosystems to health is to value all goods and services provided by ocean ecosystems in the national income accounts, including wealth accounts. If this is not done, there will be a continuing tendency to undervalue their contribution to sustainable economic welfare, and consequently to underinvest in sustainable marine ecosystems (Beck and Lange 2016; Fenichel et al. 2020).

Bringing the value of blue natural capital into The Changing Wealth of Nations (CWON) puts the value of these assets into the broader macroeconomic framework. It shows decision-makers the current status of such capital (often degraded and depleted), the threat of inaction under climate change, and the potential to greatly increase the contribution of blue natural capital to the economy if it is managed sustainably. Blue natural capital accounts are defined to include all the natural capital assets on the coast and in the marine environment.[2] They include assets as diverse as marine fisheries and mariculture; mangroves, coral reefs, seagrass beds, and other nearshore ecosystems; deltas and estuaries; offshore energy; and coastal lands used for many purposes. CWON 2021 takes the first step toward building global blue natural capital accounts. Expanding work on marine fisheries that began in CWON 2018 (De Fontaubert, Sumaila, and Lange 2018), CWON 2021 begins with accounts for mangroves and fisheries. Other assets will be included in future editions of the CWON as data become available.

The value of mangrove assets is estimated for 62 nations in the CWON database covering approximately 700,000 kilometers (km) of tropical and subtropical coastlines.[3] The asset value of fisheries is estimated for all 111 coastal countries in the CWON database, although the Sea Around Us (SAU) database includes 196 countries.[4] Blue natural capital is especially important for Small Island Developing States, but many are absent from the CWON because of the lack of information for other key assets in the wealth accounts, notably, produced capital and human capital.

Measuring the Asset Value of Mangroves and Fisheries

The two assets, mangroves and fisheries, are compiled for all CWON coastal countries from 1995 to 2018. Mangroves, like other forests, can provide multiple services, including coastal protection services, timber and nonwood forest products, and carbon storage. The mangrove accounts here focus on coastal flood protection; other values are captured in the

CWON forest accounts.[5] Fisheries accounts are based on catch data from the SAU and the fisheries economic data from the Fisheries Economics Research Unit (FERU), both based at the University of British Columbia's Institute for the Oceans and Fisheries. This chapter briefly describes the methods and data sources. For each asset, technical papers that go into much greater detail on the methodology and results are available on the CWON website (Beck et al. 2021; Lam and Sumaila 2021).

Asset valuation is based on assumptions about the future generation of the economic benefits of mangroves and fisheries. The CWON core accounts start with the simple assumption explained in chapter 2, applied to all the CWON natural capital accounts, that the benefits continue at the same level into the future for 100 years and are discounted by 4 percent. Alternative scenarios are then considered for the future under climate change and potential policy reform that might put countries on a path toward more sustainable management of their blue natural capital.

Mangroves

Mangroves provide coastal protection by reducing flooding and the resulting damages to produced capital that would occur from storms if the mangroves were absent (figure 6.1). The "avoided damage" valuation approach, which is commonly used by economists, uses the cost of

FIGURE 6.1 How Mangroves Protect Coastal Assets from Flooding

Source: World Bank 2019.
Note: The figure shows the key steps and data for estimating the flood protection benefits provided by mangroves. Offshore dynamics: oceanographic data are combined to assess offshore sea states. Nearshore dynamics: waves are modified by nearshore hydrodynamics. Habitat: effects of mangroves on wave runup are estimated. Impacts: flood heights are extended inland along profiles (every 1 kilometer) for 1 in 5-, 10-, 25-, 50-, and 100-year events with and without mangroves. Consequences: the land, people, and built capital damaged under the flooded areas are estimated.

damages prevented by mangroves to estimate the value of their coastal protection benefits. For the CWON's mangrove accounts, this value is estimated using a combined set of process-based storm and hydrodynamic models,[6] which are commonly used by engineers and risk modelers. The models identify the area and depth of flooding (1) in scenarios with and without mangroves and (2) for five storm frequency events: 1 in 5, 10, 25, 50, and 100 years,[7] driven by local storm data. Flood maps (that is, flood extent and depth) are overlaid on produced capital stock and population, downscaled to 90 x 90 meters to identify a probabilistic distribution of flood damages (risk) and avoided damages (habitat benefits). Direct estimates of the value of flood risk and mangrove benefits were made for 1996, 2010, and 2015, three years with global data on the historical distribution of mangroves, and interpolated between those years to cover the CWON period from 1995 to 2018. The data report only mangrove *cover*; additional information that can affect mangroves' ability to reduce flooding, such as the species and age composition, is not yet available.

For calculating asset value, avoided damage per hectare was treated as equivalent to resource rent used to estimate asset value for other natural capital. For the core accounts, asset value is based on the value of mangroves in a given year, assuming a 100-year lifetime and 4 percent discount rate. The value under alternative scenarios considers the benefits of partial mangrove restoration and the impact of further loss resulting from climate change and continued coastal development at the expense of mangroves.

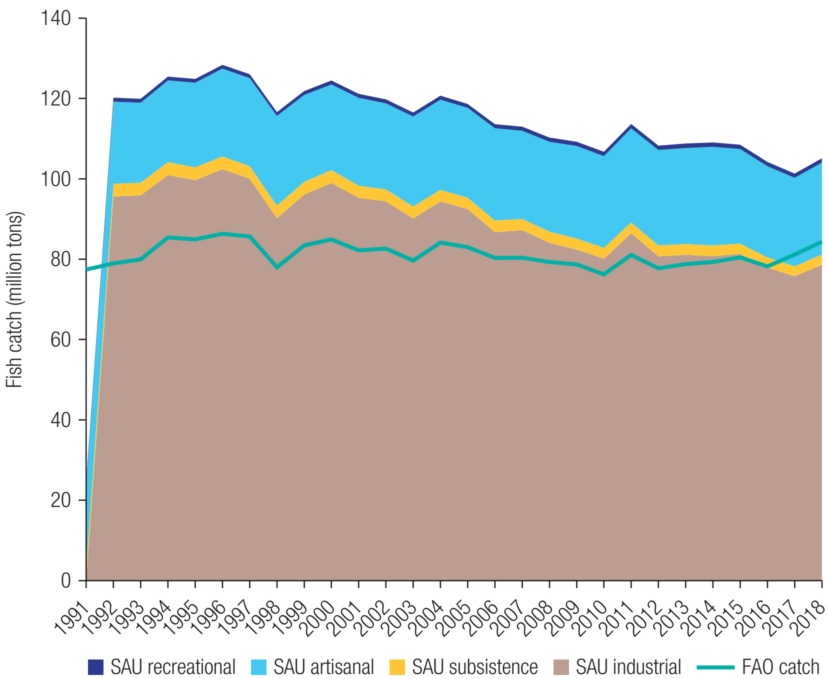
Fisheries

Resource rent is a key concept for wealth accounting and, more broadly, fisheries management. It represents the value that the asset—in this case, fisheries—contributes to fishing revenue. The revenue generated by fishing must cover all the costs: fuel, vessel costs (a "reasonable" return on fixed capital invested in fishing), labor, and so forth. Any revenue above payments needed for these inputs is considered rent attributable to fisheries. However, if revenue from fishing is not sufficient to cover all the costs, then rents are negative. In such cases, the fish stock itself does not contribute to revenue and has a zero value in financial terms. Whether rents are positive or not depends a great deal on the fisheries management regime.

An earlier World Bank report, *The Sunken Billions*, made a first attempt to measure global rents from marine fisheries and found that massive overfishing, supported by subsidies, resulted in substantial forgone rents (World Bank and FAO 2009). A more recent update, *The Sunken Billions Revisited*, estimates that forgone rents were US$83 billion in 2012 (World Bank 2017). These findings are backed by academic studies such as Sumaila et al. (2012) and Duarte et al. (2020). The results indicate that in many cases the asset value of fisheries, *as currently managed*, is zero. The good news is that if fisheries management is reformed, fisheries are capable of generating substantial rents and would not require continued subsidies, which can act as a fiscal drag on the economy (Sumaila et al. 2019).

We use the SAU and FERU databases for catch, landed value, costs of fishing, and subsidies to estimate fisheries rents and asset values for all 111 coastal countries in the CWON database, 1995 to 2018. These databases build on Food and Agriculture Organization of the United Nations (FAO) data and expand them to include estimates of catch and economic indicators that are not always reported to the FAO, especially by small-scale fisheries (figure 6.2). The gap between the SAU and FAO catch databases has been closing in recent years as FAO data become more inclusive. The SAU and FERU databases are more comprehensive than the FAO data in several additional ways that are critical for the CWON: these databases (1) disaggregate catch and landed value into four major categories, while the FAO reports only total catch; (2) spatialize catch and landed value, which is necessary for understanding the impacts of climate change; and (3) include the cost of fishing, which is needed to calculate resource rent as well as fishing subsidies. The SAU catch data are broken into four categories: industrial, artisanal, subsistence, and recreational fisheries at the level of species groups. This chapter reports total national catch; detailed spatialized information by type of fishing and at the species level can be obtained from Lam and Sumaila (2021) and the SAU website.

FIGURE 6.2 Global Fish Catch, 1991–2018



Source: Sea Around Us database, http://www.seaaroundus.org.
Note: The SAU catches in 2017 and 2018 are estimated by using the proportion of the SAU catch to that reported by the FAO in 2016 and the FAO production data in 2017 and 2018. The FAO does not disaggregate catch by type of fishery. FAO = Food and Agriculture Organization; SAU = Sea Around Us.

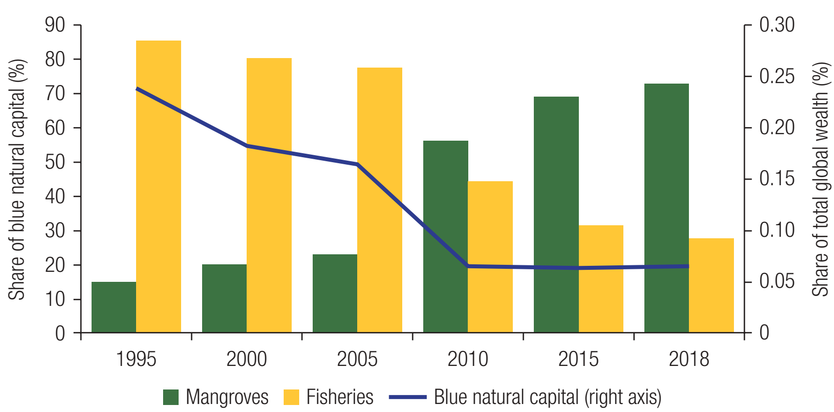
For the core accounts, fisheries asset value is based on the resource rent generated in a given year, assuming a 100-year lifetime of continued rent and 4 percent discount rate. This approach does not explicitly quantify the change in fisheries stocks because, unlike other natural capital assets, global estimates of the stocks of all the species groups for all countries are not currently available. However, estimates of the sustainability of current fishing operations as well as estimates of the impact of climate change on species distribution and abundance are available. This information is used to construct alternative scenarios of the value of fisheries.

Blue Natural Capital

At the global and regional levels, blue natural capital from mangrove coastal protection and fishery production appears quite small, at less than 1 percent of all wealth in all years and declining over time (figure 6.3; table 6.1). The relative importance of mangroves and fisheries in blue natural capital has reversed over time: fisheries' share declined from 85 to 27 percent of blue natural capital, while mangroves grew and became the dominant component of blue natural capital. In all regions except South Asia, the value of fisheries declined, while the value of mangroves increased in all regions except North America.

The importance of blue natural capital varies a great deal by country. Focusing on the 15 countries where the share of blue natural capital in total wealth is greatest (table 6.2), the changes between 1995 and 2018 are striking. In 1995, blue natural capital accounted for at least 10 percent of wealth in six countries, and all but two (Guyana and Suriname) had

FIGURE 6.3 Shares of Mangroves and Fisheries in Blue Natural Capital, and Share of Blue Natural Capital in Total Wealth, 1995–2018



Source: World Bank staff calculations.
Note: Blue natural capital is the sum of mangrove assets valued for coastal protection services and marine capture fisheries.

TABLE 6.1 Mangrove and Fisheries Wealth, by Region, 1995 and 2018
2018 US$ (millions)

	1995			2018		
Region	**Blue natural capital**	**Mangroves**	**Fisheries**	**Blue natural capital**	**Mangroves**	**Fisheries**
East Asia and Pacific	687,964	114,531	573,433	500,282	404,961	95,322
Europe and Central Asia	177,671	n.a.	177,671	31,439	n.a.	31,439
Latin America and the Caribbean	430,794	42,259	388,535	78,707	60,028	18,679
Middle East and North Africa	21,918	9,921	11,997	20,234	11,204	9,030
North America	65,863	30,254	35,609	47,938	25,580	22,358
South Asia	18,486	12,229	6,257	53,623	38,132	15,491
Sub-Saharan Africa	35,703	3,718	31,985	22,272	7,631	14,642
World	**1,438,399**	**212,913**	**1,225,486**	**754,495**	**547,534**	**206,961**

Source: World Bank staff calculations based on Beck et al. 2021.
Note: n.a. = not applicable.

TABLE 6.2 Blue Natural Capital as a Share of Wealth in the Top 15 Countries, 1995 and 2018
percent

1995				2018			
Country	**Total blue natural capital**	**Mangroves**	**Fisheries**	**Country**	**Total blue natural capital**	**Mangroves**	**Fisheries**
Belize	27.4	4.1	23.3	Suriname	21.3	21.2	0.2
Peru	21.5	0.0	21.5	Guyana	13.5	13.2	0.3
Guyana	20.4	16.3	4.0	Belize	4.6	2.8	1.8
Suriname	16.9	16.1	0.8	Vietnam	4.1	3.6	0.4
Maldives	14.5	0.0	14.5	Mauritania	2.4	0.4	2.1
Namibia	10.7	0.0	10.7	Solomon Islands	2.0	0.3	1.7
Thailand	6.2	0.1	6.1	Comoros	1.7	0.4	1.3
Malaysia	4.0	0.1	3.8	Senegal	1.7	0.3	1.3
Gambia, The	3.0	0.1	3.0	Haiti	1.2	1.2	0.0
Mozambique	3.0	0.2	2.9	Cambodia	0.9	0.7	0.2
Guinea	3.0	0.1	2.8	Guinea	0.9	0.3	0.6
Argentina	2.6	0.0	2.6	Iceland	0.8	0.0	0.8
Iceland	2.5	0.0	2.5	Papua New Guinea	0.6	0.3	0.2
Sierra Leone	2.5	0.2	2.3	Sierra Leone	0.6	0.1	0.5
Sri Lanka	2.4	0.1	2.3	Jamaica	0.5	0.5	< 0.1

Source: World Bank staff calculations based on Beck et al. 2021.

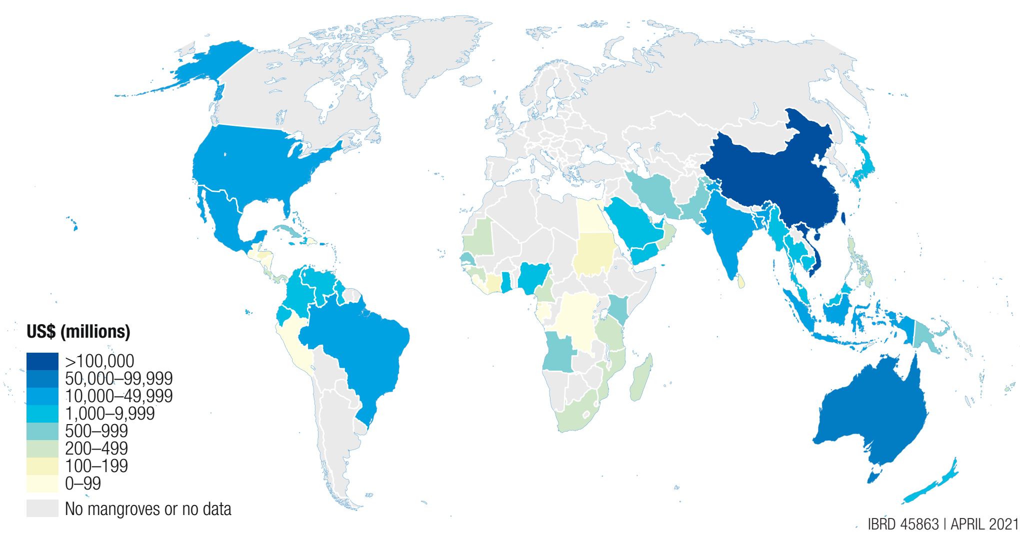
high fisheries wealth. By 2018, only two countries (Suriname and Guyana) had blue natural capital that accounted for more than 10 percent of total wealth, and, in most countries, fisheries wealth had dwindled so that mangroves now dominated.

Mangroves

The value of mangroves for flood protection and how the value has changed over time depend on several factors: the extent of mangroves,[8] the flood risk, and the produced capital at risk of damage from flooding. A country may have vast mangrove forests, but if those forests are not protecting much capital from flood risk, their value will be lower than a smaller mangrove forest protecting a more highly developed area with more capital at risk. Even if there are no changes in mangrove cover or the quantity of capital at risk, an increase in the frequency and intensity of storms can increase overall risk and the value of mangroves. Map 6.1 shows the value in 2018 across countries.

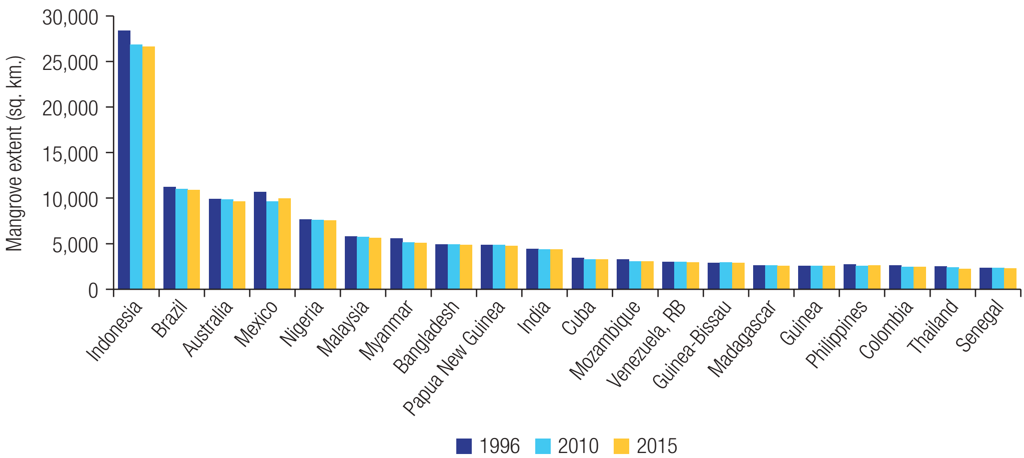
Indonesia leads the world in mangrove extent, followed by Brazil, Australia, Mexico, and Nigeria (figure 6.4). Globally, mangrove extent declined 4 percent, from 151,000 km^2 in 1996 to 145,000 km^2 in 2010, and slightly more from 2010 to 2015 (less than 1 percent). Much of the loss resulted from conversion of mangroves for aquaculture and oil palm plantations in addition to coastal development. Mangrove coverage

MAP 6.1 Mangrove Wealth, 2018



Source: World Bank staff calculations based on Beck et al. 2021.

FIGURE 6.4 Mangrove Extent in the Top 20 Countries, 1996, 2010, and 2015



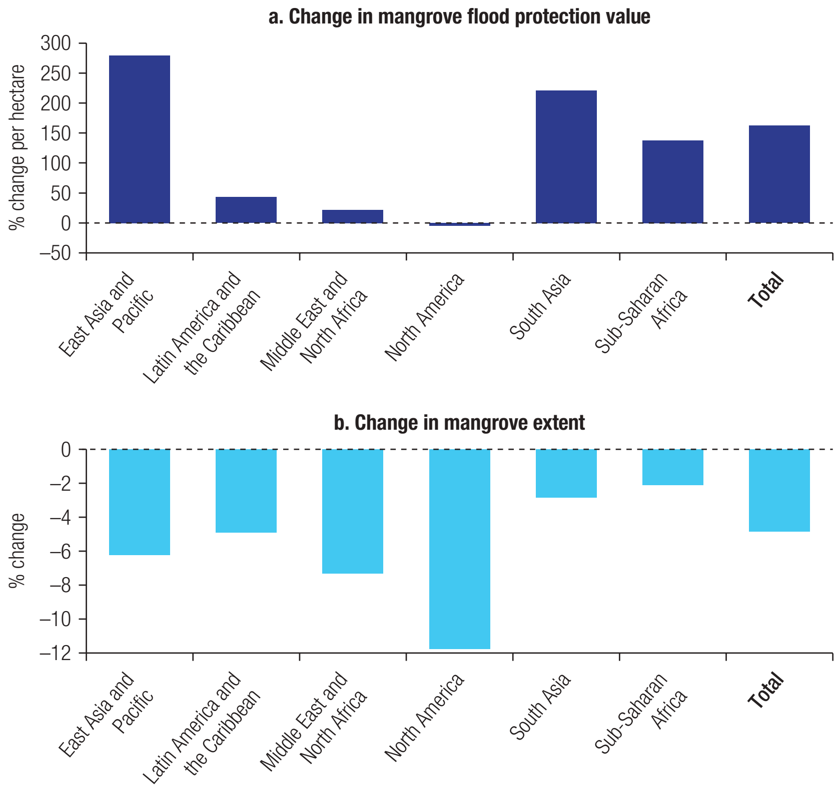
Source: World Bank staff calculations based on Beck et al. 2021.
Note: sq. km. = square kilometers.

declined in almost all countries, but in a few countries it increased or recovered after 2010, for example, Mexico and Cuba.

Although the extent of mangroves has declined somewhat since 1995, their overall value for coastal protection has increased substantially because of sharp increases in coastal flood risk driven by the growth in coastal populations and wealth (figure 6.5; table 6.3). From 1995 to 2018, the number of people directly affected by flooding in mangrove areas grew by 66 percent, and capital stock damages grew by 268 percent. Without mangroves, increased flood damage would have been even greater. In 2018, mangroves protected more than 6 million people from annual flooding and prevented additional annual losses of US$24 billion of produced capital.

As produced capital increased at the global level, so did the value of the mangroves protecting that capital. The annual benefit per hectare more than doubled between 1995 and 2018, from a global average of US$643 to US$1,689 per hectare. The asset value increased accordingly. The fastest growth in mangrove value occurred in several economies where mangrove coverage increased and the value per square kilometer of protected assets grew: China; Vietnam; Bangladesh; Japan; Taiwan, China; India; and Indonesia. Countries like Jamaica, Cuba, Thailand, and the Philippines lost considerable value where there was a decline in mangrove cover and coastal population density (table 6.4).

FIGURE 6.5 Change in Mangrove Value and Extent, by Region, 1995–2018



Source: World Bank staff calculations based on Beck et al. 2021.

TABLE 6.3 Mangrove Cover and Flood Reduction Benefits to People and Capital Stock, by Region, 1995 and 2018

a. Mangrove cover and value, 1995

Region	Mangrove area (hectares)	Population affected by flooding in 1995 (thousands)	Population protected by mangroves: Persons protected (thousands)	Population protected by mangroves: Persons per hectare	Capital stock lost to flooding in 1995 (2018 US$, millions)	Capital stock damages averted by mangroves: Capital stock (2018 US$, millions)	Capital stock damages averted by mangroves: Stock per hectare (2018 US$)
East Asia and Pacific	6,431,418	13,079.7	3,164.9	0.49	26,841	4,852	754
Latin America and the Caribbean	4,117,950	374.5	280.1	0.07	2,656	2,482	603
Middle East and North Africa	25,462	139.8	43.0	1.69	948	405	15,900

(*continued on next page*)

TABLE 6.3 Mangrove Cover and Flood Reduction Benefits to People and Capital Stock, by Region, 1995 and 2018 *(continued)*

a. Mangrove cover and value, 1995 *(continued)*

Region	Mangrove area (hectares)	Population affected by flooding in 1995 (thousands)	Population protected by mangroves: Persons protected (thousands)	Population protected by mangroves: Persons per hectare	Capital stock lost to flooding in 1995 (2018 US$, millions)	Capital stock damages averted by mangroves: Capital stock (2018 US$, millions)	Capital stock damages averted by mangroves: Stock per hectare (2018 US$)
North America	213,175	118.6	32.3	0.15	6,910	1,235	5,791
South Asia	1,031,613	599.2	806.0	0.78	402	499	484
Sub-Saharan Africa	3,155,012	161.5	130.0	0.04	277	159	51
Total	**14,974,630**	**14,473.3**	**4,456.3**	**0.30**	**38,034**	**9,632**	**643**

b. Mangrove cover and value, 2018

Region	Mangrove area (hectares)	Population affected by flooding in 2018 (thousands)	Population protected by mangroves: Persons protected (thousands)	Population protected by mangroves: Persons per hectare	Capital stock lost to flooding in 2018 (2018 US$, millions)	Capital stock damages averted by mangroves: Capital stock (2018 US$, millions)	Capital stock damages averted by mangroves: Stock per hectare (2018 US$)
East Asia and Pacific	6,030,855	20,905.6	4,408.8	0.73	120,839	17,260	2,862
Latin America and the Caribbean	3,916,230	652.3	395.4	0.10	4,995	3,383	864
Middle East and North Africa	23,601	469.3	190.8	8.08	1,449	457	19,372
North America	188,090	179.8	38.8	0.21	10,227	1,044	5,550
South Asia	1,002,190	1,294.5	1,051.8	1.05	1,729	1,556	1,553
Sub-Saharan Africa	3,088,605	465.8	239.3	0.08	605	371	120
Total	**14,249,571**	**23,967.3**	**6,324.8**	**0.44**	**139,844**	**24,071**	**1,689**

Source: World Bank staff calculations.
Note: The Europe and Central Asia region is not included in the table because it has no mangrove assets. Population affected by flooding is the number affected with current mangrove cover. Population protected by mangroves equals the *additional* number of people who would be flooded if all mangroves were lost. Capital stock lost to flooding is the annual loss in a given year with current mangrove cover. Capital stock damages averted by mangroves are the *additional* losses that would occur if all mangroves were lost.

TABLE 6.4 Mangrove Asset Value of the Top 19 Economies, 1995 and 2018

2018 US$ (millions)

Economy	Asset value, 1995	Asset value, 2018	% change
China	20,714	179,630	767
Vietnam	18,686	129,172	591
Bangladesh	2,040	10,236	402
Japan	1,108	4,554	311
Taiwan, China	2,937	10,777	267
India	9,671	28,394	194
Indonesia	12,822	31,135	143
Suriname	5,735	10,798	88
Mexico	11,784	17,838	51
Brazil	9,339	14,047	50
Australia	42,188	56,072	33
United States	29,357	27,799	–5
Ecuador	1,416	1,317	–7
Guyana	8,097	7,236	–11
United Arab Emirates	8,901	7,823	–12
Jamaica	1,337	1,123	–16
Cuba	1,437	979	–32
Thailand	4,077	2,279	–44
Philippines	10,788	5,439	–50
Subtotal	**241,573**	**496,429**	**105**
Global total	**212,913**	**547,534**	**157**

Source: World Bank staff calculations based on Beck et al. 2021.

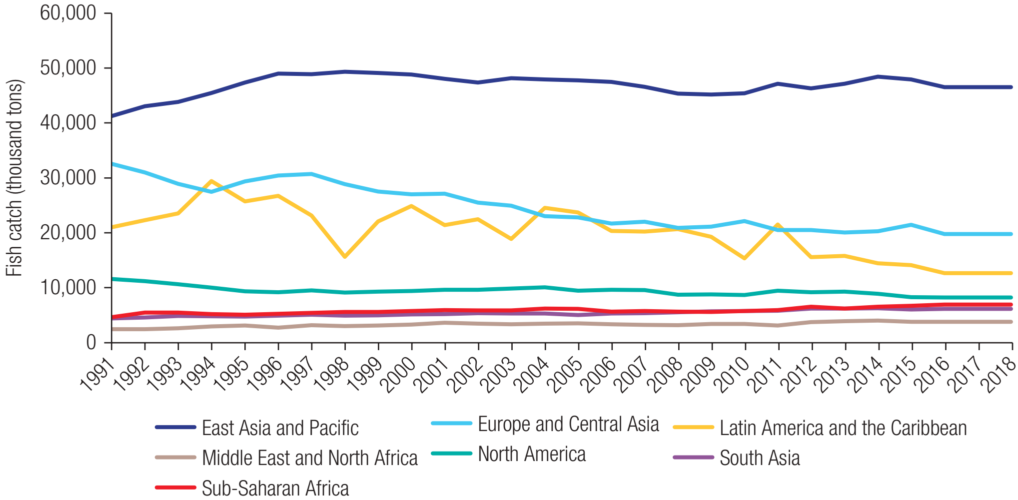
Fisheries

Fish Stocks

Globally, the story of marine fisheries from 1995 to 2018 has largely been one of stagnating catch, rising fishing costs resulting from overcapacity and overfishing (too many boats chasing too few fish), and declining rents, which resulted in declining fish asset value (figure 6.6 and figure 6.7). Rents from fishing have declined from roughly 25 percent of landed value in the 1990s to 9 percent in the 2010s, a pattern found in most countries. In some countries, rents have become negative, and fishing is financially viable only with subsidies.

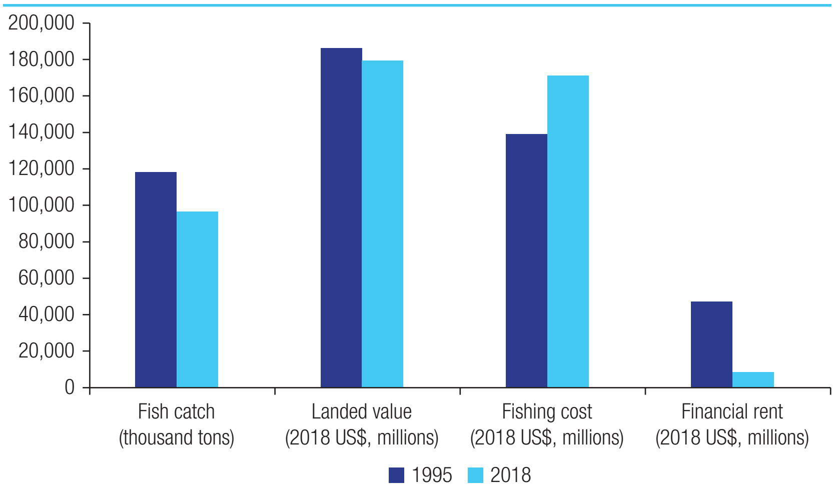
There are examples of fish stocks being rebuilt with effective fisheries management in recent decades, and it is crucial to understand the current status of fish stocks to identify strategies for recovery. The traditional stock assessment techniques require reliable estimates of stock biomass, but

FIGURE 6.6 Global Fish Catch, by Region, 1991–2018



Source: World Bank staff calculations based on Lam and Sumaila 2021.

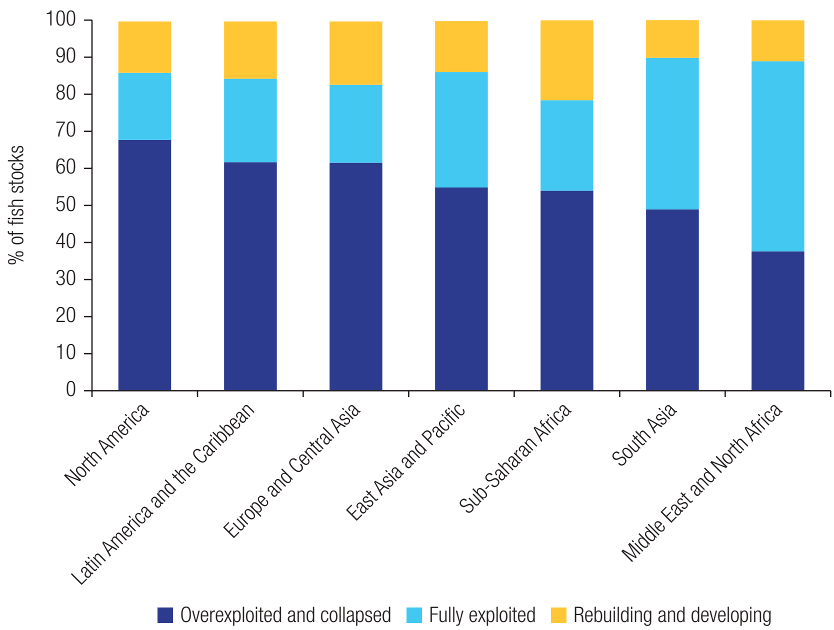
FIGURE 6.7 Global Fish Catch, Landed Value, Fishing Costs, and Financial Rent, 1995 and 2018



Source: World Bank staff calculations based on Lam and Sumaila 2021.

these are available only for a small fraction of the world's exploited stocks. SAU has developed an alternative approach based on five stages of exploitation: rebuilding, developing, fully exploited, overfished, and collapsed. For simplicity, the CWON collapses the five stages into three: (1) rebuilding and developing, (2) fully exploited, and (3) overexploited and collapsed.

FIGURE 6.8 Fish Stocks, by Exploitation Status and Region, 2018



Source: World Bank staff calculations based on Lam and Sumaila 2021.

Stock status plots are based on catch levels for a taxon (that is, at the species, genus, or family level of taxonomic assignment) relative to the maximum or peak catch of the time series (2005–14) for that taxon. The criteria for assigning a stock to a stage of exploitation and the data used for this are described in Lam and Sumaila (2021). At the national level, the percentage of fish stocks in each exploitation status is used to assess the overall stock status and hence the effectiveness of the management measures in each country.

The majority of countries had a high percentage (≥ 50 percent) of fish stocks in the overexploited and collapsed status in the 2010s, indicating poorly implemented and ineffective fisheries management. All income groups have a high percentage of fish stocks in the overexploited and collapsed status (48 to 59 percent), and countries in the high-income group have the largest percentage of fish stocks in this status (59 percent). North America has the highest percentage (68 percent), followed by Latin America and the Caribbean and Europe and Central Asia, sharing the second-highest percentage of overexploited and collapsed stocks (62 percent) (figure 6.8).

Fisheries Rents, Asset Values, and Subsidies

While the long-term global trend for financial rents (landed value minus costs) has been downward, there is a great deal of variation among countries. In 1995, 26 countries had negative financial rents, but most large fishing nations generally earned positive rents, and fisheries wealth was substantial. By 2018, rents as a share of landed value were far lower, but no country had negative financial rents, although many had near-zero rents and correspondingly low asset value. Assuming that rents, will continue to be generated in the future, global asset values fell from US$1,225 billion in 1995 to US$207 billion in 2018, a decline of 83 percent, largely because of the poor management of fisheries, before any impact of climate change on future catch is considered. Furthermore, this estimate of wealth is only the private financial value, which has been buttressed by heavy subsidies, mostly for industrial fisheries (Schuhbauer et al. 2020).

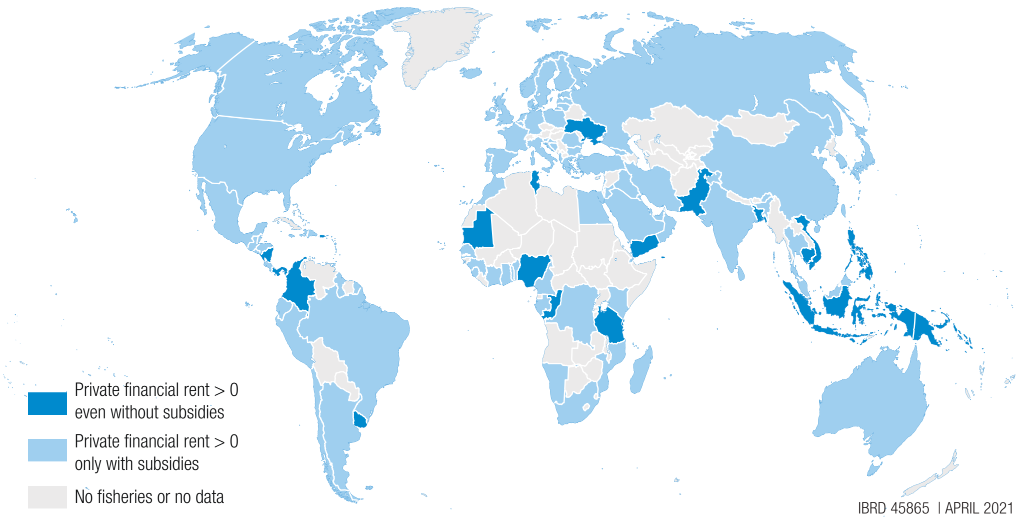
Subsidies to the private costs of fishing are widespread and can be beneficial, harmful, or neutral for the sustainable management of fisheries (Sumaila et al. 2010; Sumaila et al., forthcoming). For example, government expenditures to monitor fish stocks and set sustainable catch limits are considered good subsidies because they promote sustainable management. By contrast, capacity-enhancing subsidies, such as fuel subsidies, are harmful to sustainable fishing because they increase the fishing effort and the pressure on fish stocks. In the short term, this may increase catch and revenues, but in the long term it drives up costs and reduces the long-term sustainable catch. This analysis considers the effect of harmful subsidies that constitute a drain on government resources and a force that drives unsustainable fishing (Sakai, Yagi, and Sumaila 2019). These subsidies include, in order of magnitude, fuel subsidies, fees paid for access to foreign fishing grounds, and tax exemptions.

Subsidies drive a wedge between financial rents accruing to the private sector and economic rents adjusted for the subsidies; economic rents represent the full cost of fishing to society. To calculate economic rent, subsidies are subtracted from private financial rent. Subsidies were equivalent to 21 percent of global landed value in 1995 and 15 percent in 2018, a decline in absolute value and as a share of landed value. When only the three types of harmful subsidies are considered, they are equivalent to almost the same percentage of landed value in 1995 and 2018 (that is, about 9 percent of the total landed value). Globally, although economic rent was still positive (barely) in 1995, it was negative by 2018. Even in 1995, economic rent was negative for 72 of the 110 countries in the CWON; by 2018, that number reached 89 (map 6.2). Clearly, there is a great need for fisheries reform if the goal is to maintain fisheries for future generations.

The Future of Blue Natural Capital under Climate Change

Climate change may radically affect blue natural capital and its ability to provide benefits in this century. Policy reform has the potential to put countries on a path toward more sustainable management of their blue natural capital.

MAP 6.2 Where Fisheries Contribute to the Wealth of Nations



Source: World Bank staff calculations based on Lam and Sumaila 2021.
Note: Fisheries have positive financial asset value when private rents are positive. If harmful subsidies are considered to calculate economic rents, fisheries may not have any asset value.

Mangroves

The loss of mangroves has slowed dramatically over the past decade: less than 1 percent of mangroves was lost after 2010. The future value of mangrove flood protection through 2050 is likely to be driven strongly by changes in coastal population density and wealth. After 2050, climate change will likely play a more dominant role, but the complex interplay between population, sea level, weather events, and coastal sedimentation, among other factors, makes it difficult to predict flood risk, mangrove distribution, and protection benefits.

Mangroves face challenges from coastal development and upstream land-use changes that affect the flow of the sediment and freshwater that mangroves need to survive. By 2100, sea level rise threatens to overtake mangroves in some places unless they are able to compensate by building up sediment fast enough or migrating farther inland or to other areas that were not previously climatically hospitable to them (Blankespoor, Dasgupta, and Lange 2016).

However, mangroves face great opportunities for expansion as well as threats. As a component of nature-based solutions, mangroves are increasingly recognized as a smart way to build coastal resilience, as stand-alone solutions or combined with gray infrastructure for hybrid approaches. Mangroves provide not only resilient flood protection but also many co-benefits. Their high carbon storage capacity has made them part of climate change mitigation strategies (Browder et al. 2019).

Fisheries

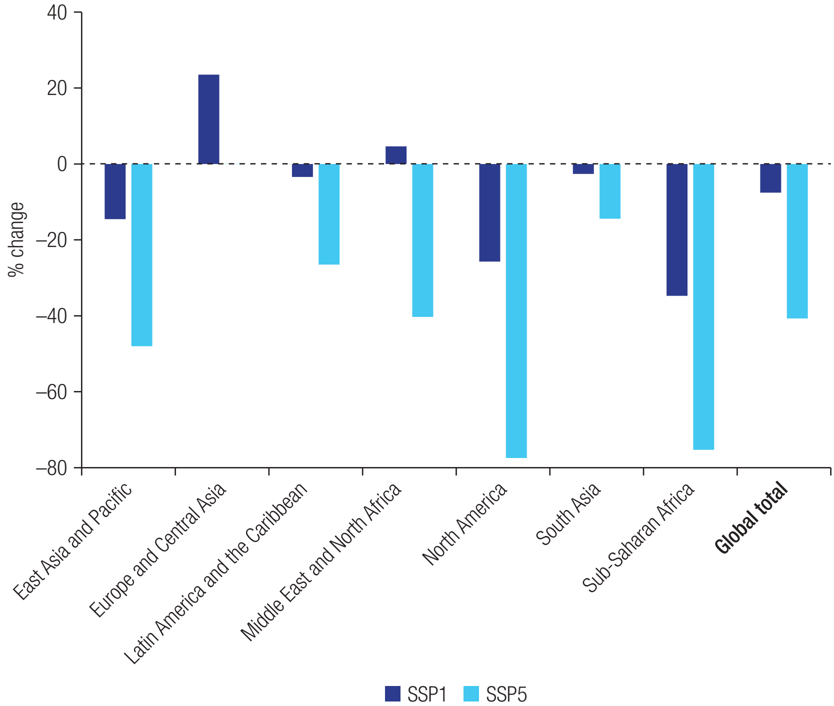
An integrated assessment model (IAM) developed for the Intergovernmental Panel on Climate Change is used to estimate the likely changes in abundance and spatial distribution at the fish stock level under two ends of the climate change scenarios: an optimistic shared socioeconomic pathway, SSP1 (low greenhouse gas emissions), and a pessimistic shared socioeconomic pathway, SSP5 (high greenhouse gas emissions). The IAM is linked to a bioeconomic model to estimate the impacts on maximum catch potential (MCP)—equivalent to the catch at maximum sustainable yield—and landed value of MCP under these scenarios. The scenarios assume that the catch does not exceed MCP and is sustainable. Under SSP1, global catch declines over this century by 1.4 percent, with slight gains in Europe and Central Asia (6.9 percent). But under SSP5, the decline in MCP reaches 9.3 percent by 2100. The decline in global landed value follows similar trends, declining by 1.6 percent under SSP1 and 8.6 percent under SSP5, with slight gains in Europe and Central Asia, which receives some fish species pushed away from tropical regions by the warming climate. These changes affect resource rents and the asset value of fisheries (table 6.5 and figure 6.9). Under both scenarios, the global value of rents declines. Under the more moderate changes of SSP1, financial rents decline in all regions except Europe and the Middle East, where rents increase by 24 and 5 percent, respectively. Under SSP5, global financial rents fall by 41 percent, declining in all regions. North America and Sub-Saharan Africa are especially hard-hit, losing 78 and 75 percent of potential rents, respectively.

TABLE 6.5 Projected Fisheries Change by 2100 Relative to 2018 in MCP and Landed Value under Climate Change Scenarios, by Region

Region	Catch, 2018 (million tonnes)	Change in MCP by 2100 (%)		Landed values, 2018 (US$, billions)	Change in landed value by 2100 (%)	
		SSP1	SSP5		SSP1	SSP5
East Asia and Pacific	49	–4	–11	81	–3	–10
Europe and Central Asia	27	7	2	39	4	0
Latin America and the Caribbean	21	–3	–14	28	–1	–9
Middle East and North Africa	3.5	–3	–19	5.6	1	–8
North America	10	–2	–14	25	–5	–16
South Asia	5.5	–1	–10	6.0	0	–1
Sub-Saharan Africa	6.1	–6	–15	8.2	–5	–12
Others (unallocated, high seas)	**0.7**	**–15**	**–47**	**1.7**	**–14**	**–47**
Total	**123**	**–1**	**–9**	**194**	**–2**	**–9**

Source: World Bank staff calculations based on Lam and Sumaila 2021.
Note: MCP = maximum catch potential; SSP1 = low-emissions shared socioeconomic pathway; SSP5 = high-emissions shared socioeconomic pathway; tonne = metric ton, i.e., unit of mass equal to 1,000 kilograms or 2,204.6 pounds.

FIGURE 6.9 Impacts of Climate Change on Fisheries: Change in Private (Financial) Rent Relative to 2018 under Alternative Climate Change Scenarios, by Region



Source: World Bank staff calculations based on Lam and Sumaila 2021.
Note: SSP1 = low-emissions shared socioeconomic pathway; SSP5 = high-emissions shared socioeconomic pathway.

Conclusion

Blue natural capital is a relatively small share of global wealth, but it is very important for many developing countries. From 1995 to 2018, much of the value of marine fisheries was lost because of poor management and overfishing, and mangrove cover, while increasing in value, did not improve. Both components of blue natural capital face serious threats from the impacts of climate change. Fish stocks and their asset value declined almost everywhere even under moderate climate change scenarios. Mangroves' ability to provide flood protection faces threats from coastal development in the coming decades, and greater threats from the sea level rise and increased weather events that are likely under climate change after 2050.

The good news is that policy reform has the potential to put countries on a path toward more sustainable management of their blue natural capital; this can increase the economic benefits from mangroves and fisheries. With improved management, fisheries can generate substantial rents without the subsidies that act as a fiscal drag on economies. Mangroves can be restored in some places, and they are increasingly recognized as a smart, nature-based way to help build coastal resilience to flooding. An additional incentive for mangrove restoration is their high capacity to store carbon, which has made them part of climate change mitigation strategies.

Notes

1. The “blue” economy is the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems. It encompasses economic sectors such as fisheries, maritime transport, tourism, and others dependent on ocean ecosystems (World Bank and UN 2017). In this report blue natural capital refers only to mangroves and fisheries.
2. A new thematic edition of the System of Environmental-Economic Accounting (SEEA) has been proposed for ocean accounting—SEEA Ocean—and technical guidelines are being developed. Ocean accounts are broader than blue natural capital because they include natural capital and produced capital in the coastal and marine space, such as port and transportation infrastructure, tourism infrastructure, residential and commercial real estate, and produced capital that generates offshore energy and mining.
3. Mangroves occur in 110 countries, but several countries were excluded from the analyses mainly because the mangrove area was too small (<100 hectares) for reliable estimation of the flood risk reduction benefits.
4. Sea Around Us database, http://www.seaaroundus.org.
5. Mangroves also protect coastlines from erosion. In future work, these additional values of mangroves would be added for a full mangrove account, but it has not been possible to do so at this time.
6. Coastal protection services can also be modeled using index-based approaches, which are less quantitative and do not directly account for storms, bathymetry, topography, and flooded assets. See Beck and Lange (2016) for a comparison of the two approaches.
7. With a percent chance of occurrence in any given year of 20, 10, 4, 2, and 1 percent, respectively.
8. Mangrove condition also affects the ability to provide flood protection, but information on this is not available at this time.

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7

Human Capital: Global Trends and the Impact of the COVID-19 Pandemic

Kenan Karakulah, Glenn-Marie Lange, and Esther Naikal

Main Messages

- Human capital—estimated as the present value of future earnings for the labor force, employed and self-employed—is the largest asset across all income groups, constituting 64 percent of total wealth in 2018, slightly higher than in 1995.
- Slower annual wage growth in high-income countries (roughly 1 percent) combined with aging of the labor force reduced their share of global human capital, while higher rates in some middle-income countries (up to 4 percent) increased their relative share.
- Significant disparity between male and female human capital persists across most regions and income groups, with great variation among regions: by 2018, females held 44 percent of human capital in Latin America and the Caribbean but only 13 percent in South Asia.
- Although the full, long-lasting effects of the COVID-19 pandemic are still unknown, the resulting economic downturn and associated unemployment and loss of earnings have already set back the long-term trajectory of poverty reduction. As a share of human capital, Sub-Saharan Africa and South Asia have suffered the greatest setbacks, losing 13 and 6 percent of their human capital, respectively.

Introduction

The previous edition of *The Changing Wealth of Nations* (CWON), in 2018, provided the first global set of comparable, estimated human capital based on expected lifetime earnings. It was derived from a time series of household surveys for 141 countries over two decades, from 1995 to 2014 (Lange, Wodon, and Carey 2018). Before that, previous editions of the CWON (World Bank 2006, 2011) measured human capital indirectly as a component of the unexplained residual, called "intangible capital." This edition's direct estimates of human capital allow for a deeper analysis of the role it plays in economic development and a clearer understanding of the underlying factors that drive human capital over time. This edition of the CWON builds on the human capital methodology established in CWON 2018 by expanding coverage to 146 countries from 1995 to 2018 and introducing a region- and income-specific approach to future wage growth.

The chapter is organized as follows. First, the estimation of human capital is summarized, and data sources and methodology are brieflly discussed. (The detailed methodology is included in the annex to this chapter.) The next section provides an overview of trends in human capital at the global, income group, and geographic region levels. This is followed by a more detailed look at trends in gender disparity. Finally, the potential effects of the COVID-19 pandemic on human capital are discussed, recognizing that its long-term impacts on human capital are currently unknown.

Estimating Human Capital

The World Bank estimates human capital by following the lifetime income approach developed by Jorgenson and Fraumeni (1989, 1992a, 1992b). According to this approach, human capital is estimated as the total present value of the expected future labor income that could be generated over the lifetime of the current working population. There are a number of different approaches to measuring human capital (box 7.1), but here human capital is considered to be an asset that generates a stream of future economic benefits. The same conceptual approach is applied to other assets in the wealth accounting framework.

The choice of the lifetime income approach for measuring the human capital stock reflects its advantages in bringing together a broad range of factors that shape the stock of human capital of the population. These factors include not only the total population and population structure but also the expected lifespan of people (a measure that reflects health conditions), their educational attainment, and their labor market experiences in terms of employment probabilities and earnings. An additional advantage of the lifetime income approach is that it allows changes in human capital to be described in terms of investment. These can include such things as formal and informal education; depreciation, such as deaths; and revaluation, such as changes in the labor market premiums of education (Liu 2011).

BOX 7.1 Different Approaches to Measuring Human Capital

Human capital consists of the knowledge, skills, and health that people accumulate over their lives. In addition to its intrinsic importance, human capital is a key driver of sustainable growth and poverty reduction. There are two broad approaches to measuring human capital. The first is an indicators-based approach, and the second is a monetary measure–based approach. The indicators-based approach estimates human capital based on measures of population characteristics, such as years of schooling, educational attainment, and test scores (Boarini, Mira d'Ercole, and Liu 2012). Single indicators cannot capture the various dimensions of human capital, and some indicators-based measures—like the United Nations Development Programme's Human Development Index or the World Bank's Human Capital Index—combine multiple components to produce more comprehensive human capital indexes. However, it can be challenging for composite indexes to produce an overall measure, since they must aggregate across indicators that lack a common metric (Boarini, Mira d'Ercole, and Liu 2012).

The monetary value approach calculates the total stock of human capital either indirectly or directly. The indirect approach estimates human capital residually, as the difference between the total discounted value of each country's future consumption flows (which is taken as a proxy for total wealth) and the sum of the tangible components of that wealth: that is, produced capital and the market-component of natural capital (Boarini, Mira d'Ercole, and Liu 2012). While a useful method, it has some drawbacks. First, since it is measured residually, estimates for human capital may be biased by measurement error in all the terms entering the accounting identities. Second, it does not take into account the nonmarket benefits of the various capital stocks (Liu 2011).

Direct monetary approaches to calculating the stock of human capital include the cost-based approach (for example, Kendrick 1976 and Eisner 1985) and the income-based approach (for example, Jorgenson and Fraumeni, 1989, 1992a, 1992b). The cost-based approach takes into account all the costs that are incurred when producing the human capital. Therefore, human capital wealth stock is the stream of past investments in human capital. Even though the cost-based approach is easy to apply, it relies only on production costs and does not take into account demand and supply (Boarini, Mira d'Ercole, and Liu 2012). The income-based approach takes into account future earnings that human capital investment generates, and hence human capital wealth stock is a function of these future earnings. While the cost-based approach measures human capital wealth stock from the input side, the income-based approach measures the stock of human capital from the output side (Boarini, Mira d'Ercole, and Liu 2012).

This concept of human capital differs from that of human development or human capabilities and complements the World Bank's Human Capital Project, which compiles a wide range of nonmonetary indicators of human capital (box 7.2). The CWON's measures of human capital focus on the economic benefits that a well-educated and healthy workforce generates. Although this approach emphasizes the role of human capital in generating income through wages and earnings, other essential

BOX 7.2 The Human Capital Index and the CWON's Measure of Human Capital

The World Bank's Human Capital Index (HCI) is an international metric measuring the human capital that a child born today can expect to attain by her 18th birthday, given the risks of poor health and poor education prevailing in her country. The HCI incorporates key dimensions of human capital: health (child survival, stunting, and adult survival rates) and the quantity and quality of schooling (expected years of school and international test scores). Using global estimates of the economic returns to education and health, these components are combined into an index that captures the expected productivity of a child born today as a future worker, relative to a benchmark of complete education and full health (World Bank 2020).

In The Changing Wealth of Nations (CWON), human capital is measured as the expected future earnings of the entire labor force. It is estimated as the total present value of the expected future labor income that could be generated over the lifetime of the current working population. In other words, human capital is considered an asset that generates a stream of future economic benefits. The CWON's measure of human capital focuses on the economic benefits that a well-educated and healthy workforce generates.

The HCI uses a broader concept of human capital than CWON, incorporating several nonmonetary indicators of health and education outcomes. Conceptually, however, the two measures have much in common, as both are anchored in the development-accounting literature and measure human capital in terms of expected future earnings. The main difference between the two measures is that the HCI measures expected *future earnings of a child born today,* while the CWON measure estimates expected *future earnings of the entire labor force*. In addition, while the CWON reports estimates in monetary terms, the HCI is expressed relative to a benchmark of complete education and full health: a child born in a country with an HCI value of 0.5 will be only half as productive as a future worker as she would be if she enjoyed complete education and full health.

The CWON measure of human capital complements the HCI, using human capital outcomes that derive indirectly from factors such as educational attainment and health (probability of survival) to provide an understanding of the current stock of human capital in countries. The CWON measure also importantly accounts for labor market outcomes, such as the probability of employment and labor market premiums across countries. While the HCI does not include labor market outcomes, the 2020 update to the index introduced the Utilization-Adjusted HCI. This analytical extension accounts for the underutilization of human capital, based on the fraction of the working-age population that is employed or is in the types of jobs that might better enable them to use their skills and abilities to increase their productivity.

The HCI constitutes one pillar of the World Bank's Human Capital Project (HCP) that aims to help countries make effective investments in the human capital of their citizens, a core strategy to increase productivity and foster growth. The second pillar of the HCP aims to scale up measurement and research on human capital formation and the programs and policies that support this process. The third pillar, focused on country engagement, supports governments in identifying national priorities for human capital development and implementing policies that tackle the barriers preventing countries from reaching their goals (World Bank 2018). To this end, CWON estimates of the current stock of human capital complement the HCI's forward-looking measure to further the World Bank's agenda on human capital.

Sources: World Bank (2018, 2020); the Human Capital Project.

benefits from investments in human development are recognized, such as the intrinsic value of a good education and good health. But for financial wealth accounting purposes, the focus remains strictly on the monetary estimates of wealth associated with human capital. Therefore, human capital is an underestimate, since it leaves out positive externalities, the public good benefits of an educated population, such as building social capital and trust, which are discussed in chapter 15.

Because this approach builds on the concepts and measurement of labor earnings in the System of National Accounts (SNA), the CWON human capital estimates have a major omission: human capital that produces household services such as childcare, food preparation, and home repair. The SNA accounts for household production of goods, such as food for own consumption, but does not include household production of services. Consequently, the human capital associated with production of household services is not measured, an omission that disproportionately affects the measure of women's human capital.

Data and Methodology

Data Sources

To compute human capital as the discounted value of expected future labor income, data on the population, employment, annual earnings, survival rates, gross domestic product (GDP), and labor shares are needed from different data sources. The International Income Distribution Database (I2D2), a unique database developed by the World Bank containing more than 1,500 household surveys, is used for calculating annual earnings, educational attainment, and employment rates. As population data are retrieved from the United Nations World Population Prospects, the United Nations National Accounts database is used for GDP data.

The World Bank's I2D2 database is used for the information on the number of people, their earnings, school enrollment rates, and employment rates. The Mincerian coefficients are obtained from Mincerian wage regressions utilizing the I2D2 database. Based on the results of the Mincerian regressions, a matrix of expected earnings is constructed. Therefore, the matrix accounts for labor earnings of the population by age, gender, and education level.

For simplification, the lifetime for working is assumed to be a maximum of 50 years, starting at age 15 and ending with retirement at age 65, for all countries. All individuals younger than age 15 are assumed to be in school. Individuals between ages 15 and 24 are enrolled in school or part of the labor force. Individuals in the labor force are then expected to work until age 65, after which labor income is assumed to be zero. In calculating the net present value, a uniform discount rate of 4 percent is used for human capital, in line with all resources and countries within the wealth accounting framework.

Survival rates are not readily available from the data sources. To calculate survival rates, death rates obtained from the Global Burden of Disease Study 2019 are utilized. The shares of compensation of employees and the self-employed in the national accounts are retrieved from the Penn World Table 9.1 to control the estimated wages. Finally, employment data from the International Labour Organization are used for controlling and scaling up total employment from the I2D2 database. Where some data are missing for a country in a given year, gap-filling measures are employed. The data and methods are described further in annex 7A at the end of this chapter.

Labor Income Growth Rates

A critical factor in human capital valuation is the expected change in wage rates over time. The estimates in CWON 2018 assumed the same constant wage growth rate in all countries, 2.46 percent, because of a lack of data. However, this is not realistic, because wage growth rates vary greatly across countries. CWON 2021 introduces region- and income group–specific annual real labor wage growth rates capped at 4 percent (table 7.1). The growth rates are derived from the World Bank's macroeconomic and fiscal model based on historical data and long-term projections based on potential output in each country, which builds on total factor productivity growth, capital stocks, and employment growth. These growth rates were estimated in October 2020 and include the initial negative effects of the COVID-19 pandemic on economic activity and wage growth for 2020–22. For the period after 2023, a recovery in the labor income growth rates is assumed aligned with the

TABLE 7.1 Labor Income Growth Rates, by Region and Income Level

Region	Countries	Wage growth (%)
East Asia and Pacific, high-income	4	1.08
East Asia and Pacific (excluding high-income)	11	4.00
Europe and Central Asia, high-income	27	1.08
Europe and Central Asia (excluding high-income)	17	2.83
Latin America and the Caribbean, high-income	4	1.08
Latin America and the Caribbean (excluding high-income)	20	0.96
Middle East and North Africa, high-income	7	1.08
Middle East and North Africa (excluding high-income)	10	1.34
North America	2	0.91
South Asia	6	3.60
Sub-Saharan Africa	38	1.41
Total	**146**	

Source: World Bank staff calculations.
Note: All countries in North America are high-income; all countries in South Asia and Sub-Saharan Africa are low- or middle-income.

recovery in total factor productivity growth. In addition, real labor wage growth rates are differentiated by region and income group, reflecting factors such as underlying labor market characteristics and productivity. Grouping wage growth rates by region and income group allows for a more transparent and simpler calculation, given the vast size of the database. In a later section, this chapter explores the impact of this short-term COVID-19-related loss on human capital.

Adjustments to the National Accounts and Population Data

Because the survey data do not capture the entire world population, the data from the surveys are adjusted to population estimates from the United Nations to ensure that the estimates are adequate. In addition, the earnings profiles are not compatible with the published data from the SNA because the earnings profiles from the surveys do not include any benefits other than wages, including social security payments and other wage-related payments. Hence, the estimated earnings profiles from the surveys are benchmarked to the compensation of employees and self-employed that is obtained from the Penn World Table. Therefore, expected labor earnings from the surveys are scaled up to the labor earnings in the national accounts.

Generating the Lifetime Income

After the lifetime income profiles for a representative individual cross-classified by age, gender, and education are generated, they are multiplied by the corresponding number of people in a country, and thereby the human capital stock by age, gender, and education is calculated. Summing up the stocks of human capital across all classified categories generates the estimate of the aggregate value of the human capital stock for each country.

Estimates of Human Capital

This section focuses on human capital across countries and trends in human capital over 1995–2018. The estimates of human capital are summarized at the global, income, and regional levels, with an additional discussion on the self-employed portion of human capital.

Human Capital by Income Group

Human capital is a critical component of a nation's wealth, accounting for the largest share of wealth for most countries. On average, human capital constitutes about two-thirds of total wealth at the global level, rising from 62 percent in 1995 to 64 percent in 2018 (table 7.2). The share of human capital in total wealth changes steadily with the level of development—human capital's share of total wealth generally increases as countries achieve higher levels of economic development. Human capital was greater than 60 percent of wealth in middle-income and high-income Organisation for Economic Co-operation and Development (OECD)

TABLE 7.2 Trends in Wealth per Capita, by Income Group, 1995–2018

Income group	1995	2000	2005	2010	2015	2018	Total growth (%)
Low-income							
Total wealth per capita (2018 US$)	9,379	9,121	9,250	10,228	11,306	11,462	22
Human capital per capita (2018 US$)	3,580	3,548	3,812	4,266	5,163	5,726	60
Human capital as share of total wealth (%)	38	39	41	42	46	50	n.a.
Lower-middle-income							
Total wealth per capita (2018 US$)	15,253	15,516	17,721	22,066	24,896	27,108	78
Human capital per capita (2018 US$)	8,570	8,926	10,387	13,092	14,961	16,847	97
Human capital as share of total wealth (%)	56	58	59	59	60	62	n.a.
Upper-middle-income							
Total wealth per capita (2018 US$)	50,744	58,872	74,317	100,114	128,136	141,682	179
Human capital per capita (2018 US$)	28,827	35,579	46,108	62,489	83,305	93,794	225
Human capital as share of total wealth (%)	57	60	62	62	65	66	n.a.
High-income: non-OECD							
Total wealth per capita (2018 US$)	315,088	334,226	367,631	410,083	450,258	400,891	27
Human capital per capita (2018 US$)	123,878	125,885	119,946	130,637	135,468	134,604	9
Human capital as share of total wealth (%)	39	38	33	32	30	34	n.a.
High-income: OECD							
Total wealth per capita (2018 US$)	468,398	522,668	545,341	564,426	597,897	621,278	33
Human capital per capita (2018 US$)	299,270	337,303	344,467	349,834	378,100	396,222	32
Human capital as share of total wealth (%)	64	65	63	62	63	64	n.a.
World							
Total wealth per capita (2018 US$)	111,174	120,431	128,122	140,129	153,631	160,167	44
Human capital per capita (2018 US$)	68,450	75,524	79,227	85,448	95,971	101,797	49
Human capital as share of total wealth (%)	62	63	62	61	62	64	n.a.

Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development; n.a. = not applicable.

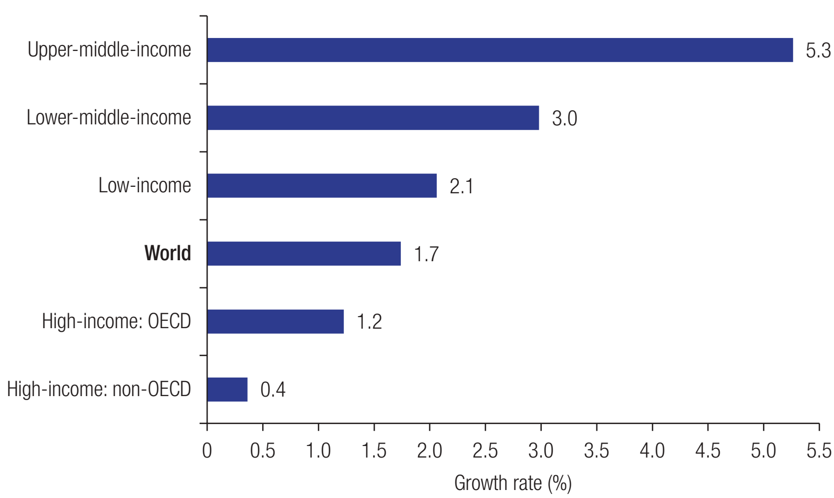
countries in 2018 but only 50 percent in low-income countries. High-income non-OECD countries—countries that are heavily dependent on fossil fuel wealth—had the lowest share, only 34 percent of wealth. It is a challenge for oil-rich countries to build human capital quickly, despite the abundant financial resources provided by oil.

Trends in human capital differ over time between high-income OECD countries and low- and middle-income countries. On average, the share of human capital in high-income countries plateaued during 1995–2018, while it increased in all other income groups. This can be explained in part by the share of labor earnings in GDP, which anchors the human capital estimates. Labor earnings as a share of GDP and per capita human capital grew rapidly in the 1990s, but much more slowly since 2000 because of technological change, stagnating wages, and in many countries, a reduction in the share of the population in the labor force, which resulted from the aging of the population. But in many middle- and low-income countries, educational attainment and returns to education are still growing, and hence human capital is growing fast.

Inequality in total wealth across income groups extends to human capital as well. Per capita human capital in high-income OECD countries in 2018 was 69 times of that in low-income countries. In high-income OECD countries, human capital per capita was close to US$400,000, while it was only US$5,726 in low-income countries (table 7.2). This significant difference between human capital in low-income and high-income countries reflects the difference in incomes.

Growth of human capital tends to be higher in middle-income countries, at 5.3 percent per year in upper-middle-income countries and 3.0 percent per year in lower-middle-income countries. The lowest growth is seen in high-income countries, at 0.4 percent per year in high-income non-OECD countries and 1.2 percent per year in high-income OECD countries (figure 7.1). This is mostly because of the differences in labor income growth rates and GDP growth rates. Labor income growth in high-income countries is significantly lower than that in low-income and middle-income countries. Moreover, on average, GDP growth rates of high-income countries are lower than GDP growth rates of low- and middle-income countries.

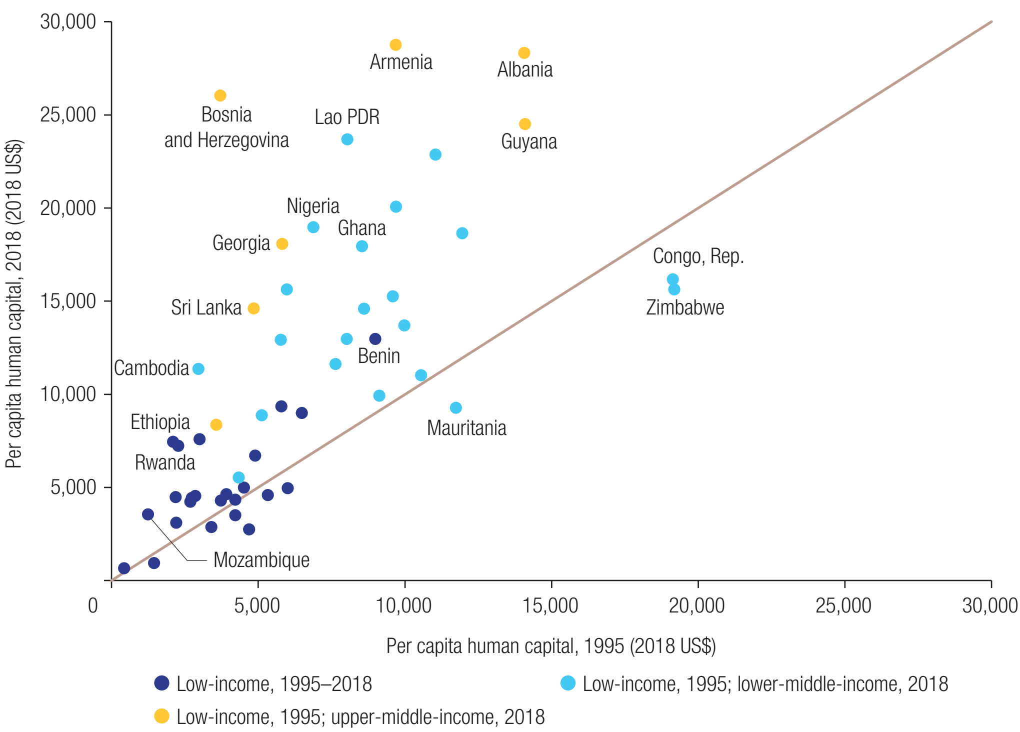
FIGURE 7.1 Annual Growth Rates of Human Capital per Capita, by Income Group, 1995–2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

Of particular interest is the pattern of growth of countries that were classified as low-income in 1995 but grew to become middle-income by 2018 (and are thus classified as middle-income in the CWON database). The transition of all these countries involved accelerated investment in and accumulation of human capital. However, there were three exceptions—countries that became middle-income largely because of fossil fuel and mineral wealth: Mauritania, Zimbabwe, and the Republic of Congo. The Republic of Congo and Zimbabwe are considered fragile and conflict-affected states in which building human capital becomes very difficult. The Republic of Congo's heavy dependence on oil created further difficulties after 2014 when oil prices fell. Although it is not a fragile and conflict-affected state, Mauritania is an example of the potential demographic dividend from population growth not being achieved, a result of underinvestment in human capital. Total human capital increased from 1995 to 2018, but the increase was not enough to compensate for the country's rapid population growth (figure 7.2).

FIGURE 7.2 Change in Per Capita Human Capital in Low-Income Countries, 1995–2018



Source: World Bank staff calculations.

Note: Although China was a low-income country in 1995 and became an upper-middle-income country in 2018, its per capita human capital is not included in the figure because of scaling. The figure includes all countries with per capita human capital less than US$30,000 in 2018. Since China's per capita human capital is far above this threshold, the figure doesn't include China while it was a low-income country in 1995, because it would distort the figure. China's per capita human capital was US$25,556 in 1995, and it skyrocketed to US$127,685 in 2018.

In general, countries that sustained their low-income status from 1995 to 2018 did not experience a meaningful change in their human capital (dark blue dots in figure 7.2). Among these countries, only Benin's per capita human capital exceeded US$10,000 from 1995 to 2018. Low-income countries that moved to middle-income status from 1995 to 2018 saw significant increases in human capital. Human capital per capita more than doubled from 1995 to 2018 in most of the current middle-income countries that were classified as low-income status in 1995 (light blue and yellow dots in figure 7.2). Per capita human capital increased by a factor of seven in Bosnia and Herzegovina, a factor of five in China, four in Cambodia, three and a half in Ethiopia, and about three in Rwanda, Georgia, Sri Lanka, Armenia, the Lao People's Democratic Republic, Mozambique, and Nigeria (figure 7.2). Furthermore, Bosnia and Herzegovina outperformed not only low-income countries but also countries at all income levels in the increase in per capita human capital. And China's per capita human capital exceeded US$100,000, reaching US$127,685 in 2018.

Regional Trends in Human Capital

Human capital constitutes a significant share of total wealth in all regions except the Middle East and North Africa, where human capital is less than one-third of total wealth. For all other regions, human capital is the largest share of total wealth. The share of human capital in total wealth increased from 1995 to 2018 in all regions except the Middle East and North Africa, where it decreased, and East Asia and Pacific, where it stayed the same (table 7.3).

There are significant variations in human capital per capita among regions. In 2018, the difference between the per capita human capital of the regions with the highest value and the lowest was 50 times. Although South Asia had the lowest per capita human capital in 1995, by 2018 Sub-Saharan Africa claimed the lowest per capita human capital. This was mostly the result of faster GDP growth in South Asian countries compared with Sub-Saharan African countries. For instance, average GDP growth in South Asia over 1995–2018 was 6.2 percent, while it was 4.2 percent in Sub-Saharan Africa. Thus, average per capita human capital in Sub-Saharan Africa in 2018 was US$12,278, while it was US$14,769 in South Asia. On the other end of the spectrum, North America had the highest per capita human capital of all regions, at US$612,452 in 2018—more than three times the per capita human capital of Europe and Central Asia. The main reason is that North America consists of only two high-income countries, while Europe and Central Asia includes countries in all income groups.

As a result of the differences in labor income growth rates, growth in human capital is higher in the South Asia and East Asia and Pacific regions, at 3.9 percent per year in both. As the methodology section suggests, labor income growth rates are higher in these regions. Moreover, most countries in these regions had the highest growth rates of the wage rate and GDP over the past 25 years, although these two regions include the two most populous countries in the world. The Middle East and North Africa,

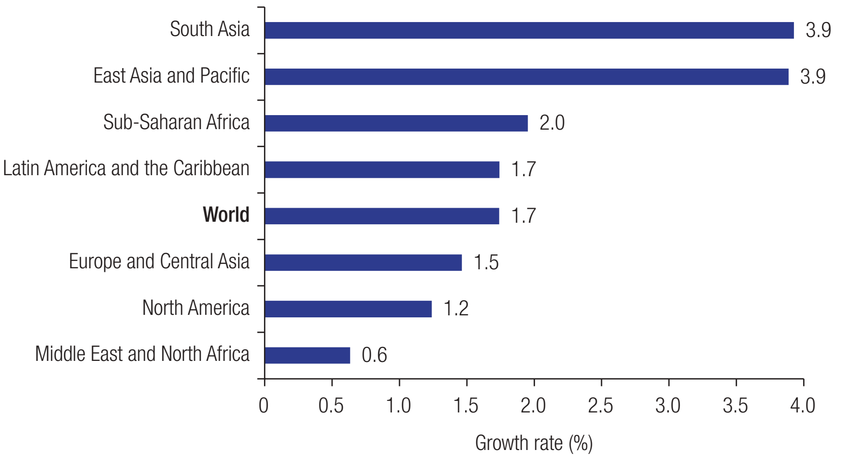
TABLE 7.3 Trends in Wealth per Capita, by Region, 1995–2018

Region	1995	2000	2005	2010	2015	2018	Total growth (%)
East Asia and Pacific							
Total wealth per capita (2018 US$)	73,518	84,441	99,076	126,270	158,301	176,125	140
Human capital per capita (2018 US$)	49,107	55,790	65,061	82,052	105,384	118,041	140
Human capital as share of total wealth (%)	67	66	66	65	67	67	n.a.
Europe and Central Asia							
Total wealth per capita (2018 US$)	237,608	257,762	276,580	296,021	309,672	322,739	36
Human capital per capita (2018 US$)	128,957	142,468	152,194	163,012	171,434	180,093	40
Human capital as share of total wealth (%)	54	55	55	55	55	56	n.a.
Latin America and the Caribbean							
Total wealth per capita (2018 US$)	75,547	78,567	83,210	94,677	106,246	107,229	42
Human capital per capita (2018 US$)	44,848	47,913	49,579	56,208	64,698	66,709	49
Human capital as share of total wealth (%)	59	61	60	59	61	62	n.a.
Middle East and North Africa							
Total wealth per capita (2018 US$)	74,030	75,920	88,615	109,212	116,929	102,927	39
Human capital per capita (2018 US$)	26,801	26,396	26,261	30,332	31,764	30,989	16
Human capital as share of total wealth (%)	36	35	30	28	27	30	n.a.
North America							
Total wealth per capita (2018 US$)	674,771	766,443	796,244	799,827	841,547	867,304	29
Human capital per capita (2018 US$)	461,403	536,869	546,905	537,602	585,338	612,452	33
Human capital as share of total wealth (%)	68	70	69	67	70	71	n.a.
South Asia							
Total wealth per capita (2018 US$)	9,648	10,964	12,944	16,168	19,791	22,680	135
Human capital per capita (2018 US$)	6,089	7,142	8,490	10,130	12,513	14,769	143
Human capital as share of total wealth (%)	63	65	66	63	63	65	n.a.
Sub-Saharan Africa							
Total wealth per capita (2018 US$)	17,273	15,528	16,018	19,527	21,003	20,473	19
Human capital per capita (2018 US$)	7,870	7,228	7,747	10,613	12,062	12,278	56
Human capital as share of total wealth (%)	46	47	48	54	57	60	n.a.

Source: World Bank staff calculations.
Note: n.a. = not applicable.

North America, and Europe and Central Asia saw the lowest growth rates in human capital, at 0.6, 1.2, and 1.5 percent per year, respectively (figure 7.3). Compared with South Asia and East Asia and Pacific, these regions consist mostly of high-income countries, where labor income growth and GDP growth tend to be lower. Moreover, most countries in the Middle East and North Africa are resource-rich countries and reliant

FIGURE 7.3 Annual Growth Rates of Human Capital per Capita, by Region, 1995–2018



Source: World Bank staff calculations.

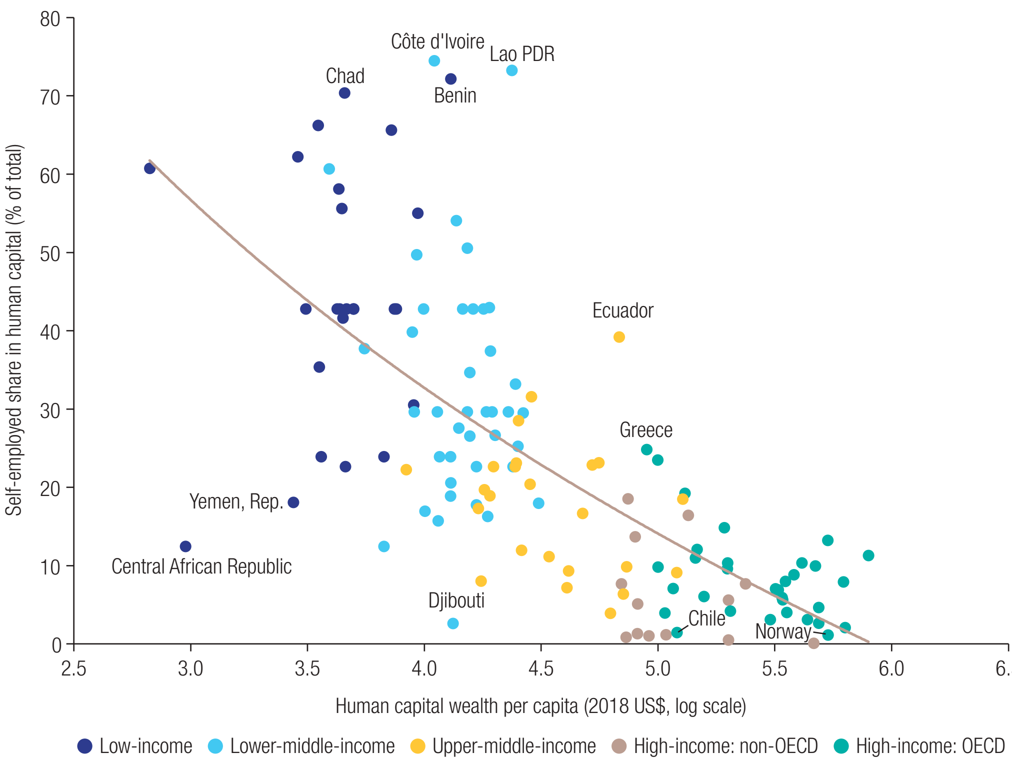
on fossil fuel energy resources, and these countries face unique development challenges to transform an exhaustible resource into assets that can continue to generate income and employment.

Human Capital and the Self-Employed

Self-employment is an important part of the labor market in many countries, but especially in low-income countries. However, estimation of the earnings of the self-employed reported in national surveys is underrepresented and poorly captured, because surveys tend to focus only on formal employment. In addition, most self-employed workers are active in agriculture, and earnings as measured in a labor force or household survey may not adequately account for these workers. This makes it difficult to estimate the share of human capital attributed to self-employment in a systematic way across countries (given differences in survey designs and questionnaires among countries). As is explained in annex 7A, the Penn World Table provides estimates of the income of the self-employed by drawing on additional data (for example, national accounts' mixed income and value added from agriculture). Therefore, disaggregating earnings by employment is done by using the Penn World Table estimates for the purpose of this chapter.

Self-employed workers account for only 13 percent of global human capital. However, the human capital of the self-employed is a large share of the total in many of the poorest countries, where the agriculture sector and informal employment are significant. In more recent years, the growth of self-employment has been increasing in higher-income-level economies. In particular, technological improvement, artificial intelligence, and automation have been paving the way for the increasing number of self-employed people in those countries.

FIGURE 7.4 Self-Employed Share in Human Capital, 2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

Figure 7.4 illustrates the strong downward relationship between the level of human capital and the share of human capital attributed to the self-employed. In general, countries with lower levels of human capital have higher shares of wealth attributed to the self-employed. This is an expected result, because self-employment (including subsistence farmers and small businesses in the informal sector) constitutes a more substantial part of total labor inputs than wage employment in these countries. By contrast, the share of human capital attributed to the self-employed in high-income countries is meaningfully low. For instance, the share of human capital attributed to the self-employed is only 1.1 percent in Norway and 1.5 percent in Chile.

Gender and Human Capital

The human capital estimates reveal a significant disparity between the male and female shares of human capital. Unfortunately, little progress has been made toward greater gender parity in human capital over the past 25 years. Globally, as shown in table 7.4, women accounted for only

TABLE 7.4 Shares of Human Capital, by Gender, 1995–2018

	Male share (%)						Female share (%)					
Income group and region	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**
Income group												
Low-income	66	66	66	67	67	68	34	34	34	33	33	32
Lower-middle-income	74	75	76	75	77	78	26	25	24	25	23	22
Upper-middle-income	63	62	62	63	63	64	37	38	38	37	37	36
High-income: non-OECD	71	70	70	72	71	71	29	30	30	28	29	29
High-income: OECD	64	64	63	62	62	62	36	36	37	38	38	38
Region												
East Asia and Pacific	70	69	67	67	67	67	30	31	33	33	33	33
Europe and Central Asia	62	62	61	61	60	61	38	38	39	39	40	39
Latin America and the Caribbean	61	58	58	57	56	56	39	42	42	43	44	44
Middle East and North Africa	75	75	75	75	74	74	25	25	25	25	26	26
North America	62	63	61	59	59	59	38	37	39	41	41	41
South Asia	88	88	87	87	87	87	12	12	13	13	13	13
Sub-Saharan Africa	56	57	62	67	67	67	44	43	38	33	33	33
World	**65**	**64**	**63**	**63**	**63**	**63**	**35**	**36**	**37**	**37**	**37**	**37**

Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

37 percent of human capital in 2018, which was only 2 percentage points greater than the 1995 level.

Although higher levels of economic development are generally associated with a higher share of women in human capital, women account for less than 40 percent of human capital at all levels of development. While women account for less than one-third of human capital in low-income, lower-middle-income, and high-income non-OECD countries, the share of women is slightly greater than one-third of human capital in upper-middle-income and high-income OECD countries.

The differences between regions are even more striking. As shown in table 7.4, women accounted for only 13 percent of human capital in South Asia in 2018, while 44 percent of human capital was attributed to women in Latin America and the Caribbean. The share of women in Europe and Central Asia and North America was about 40 percent of human capital, while about one-third of human capital was attributed to women in East Asia and Pacific and Sub-Saharan Africa.

These results demonstrate that women's role in human capital tends to increase as countries achieve higher levels of economic development. This is an expected outcome because higher educational attainment, better quality of education, higher participation of women in the labor force, and more competitive wages are associated with economic development. However, as the results suggest, there is still substantial gender disparity between men and women even in high-income countries and regions with high economic development. There are several other factors causing the gender disparity in human capital, including (1) careers that are interrupted for childbearing; (2) penalties for childcare, as women work part-time to meet family needs and as employers question the commitment of women to their career; (3) preferences on the part of women for occupations that may be lower paid, an effect that is often reinforced by preferences for fields of study that lead to such occupations; (4) barriers that prevent women from attaining similar economic opportunities as men; and (5) a lack of women in leadership positions in the workforce. Gender discrimination fosters and reinforces many of these negative influences on women's earnings.

To capture the magnitude of gender-based disparities in human capital over time, table 7.5 provides a simple measure of the gender gap in human capital, defined as the ratio of the human capital of women divided by that of men in a country. In 2018, the global gender gap in human capital was 57 percent, meaning the remaining gap to close is 43 percent. Although there was progress from 1995 to 2018, the global

TABLE 7.5 Potential Gains in Human Capital from Gender Equity, by Income Group and Region, 1995–2018

	Gender gap ratio (x100) (ratio of human capital by gender)						Potential gain from gender equity (% increase from base)					
Income group and region	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**
Income group												
Low-income	51	51	52	49	48	47	25	24	24	25	26	27
Lower-middle-income	36	33	32	34	29	28	32	33	34	33	35	36
Upper-middle-income	59	62	62	60	58	57	20	19	19	20	21	21
High-income: non-OECD	41	43	42	40	41	41	29	28	29	30	30	30
High-income: OECD	56	56	59	62	62	62	22	22	21	19	19	19
Region												
East Asia and Pacific	44	46	48	50	49	49	28	27	26	25	25	25
Europe and Central Asia	62	62	63	64	65	64	19	19	18	18	17	18
Latin America and the Caribbean	64	74	73	77	78	79	18	13	13	12	11	11
Middle East and North Africa	34	34	34	34	36	36	33	33	33	33	32	32
North America	60	59	64	69	69	69	20	20	18	15	15	15
South Asia	14	14	15	15	15	15	43	43	42	42	42	42
Sub-Saharan Africa	78	74	62	49	49	49	11	13	19	26	25	25
World	**55**	**55**	**57**	**59**	**58**	**57**	**23**	**22**	**21**	**21**	**21**	**21**

Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

progress has been minimal: only 2 percentage points. In low-income, lower-middle-income, and high-income non-OECD countries, the gender gap ratio is particularly low, below 50 percent. In other words, women's presence and contribution to human capital is still extremely limited at these levels of economic development. In countries at higher levels of economic development, the gender gap ratio is higher, but still well below parity. Interestingly, only high-income OECD countries made progress toward gender equality over 1995–2018, narrowing the gap by 6 percentage points. In contrast, the gender gap worsened in countries at all other levels of development. One possible reason why the gender gaps are widening outside high-income OECD countries could be that women's wages tend to be lower than men's wages even as women's labor force participation is increasing. However, further research is needed for a full explanation.

The gender gap in human capital across regions is even more noticeable. The gender gap ratio has a wide range, from 15 percent in South Asia to 79 percent in Latin America and the Caribbean. South Asia's large gender gap is mostly caused by a male-dominated labor force and many barriers that prevent women from attaining similar economic opportunities as men. In contrast, female labor force participation is higher in Latin America and the Caribbean. Although the gender gap ratio is higher in North America and Europe and Central Asia compared with other regions, it is still far from parity, at below 70 percent.

The gender gap in human capital can be used to conduct simple simulations of the gains that could be achieved from greater equity in earnings and thereby human capital by gender. Assume for simplicity that the working-age population is equally divided between men and women, each with a 50 percent share. Then, if the earnings of women were on par with those of men, women's human capital would rise considerably. Assuming no decrease in the human capital of men, the resulting gains in human capital (NG) can be estimated as NG = (100 − gender gap ratio) × 0.50/100. As shown in table 7.5, human capital worldwide could increase by 21 percentage points with gender parity. In low-income, lower-middle-income, and high-income non-OECD countries where the gender gaps in human capital are more pronounced, the gains from gender equity would be larger. Meanwhile, countries at all levels of economic development benefit from gender equity.

Because the gender gaps are substantially larger in some regions, the gains from gender equity in these regions are stunning. The region with the largest difference in human capital by gender is South Asia. If gender parity were achieved in South Asia, this could increase human capital nationally by roughly 42 percentage points (table 7.5). These simple simulations do not account for the general equilibrium impact that an influx of women into the labor market might generate, and thereby tend to overestimate the benefits that could result from gender equity. Still, the estimates show that major gains in human capital per capita could be achieved if women were able to work more and earn more and that deeper analysis is needed on the components driving women's human capital compared to men's.

Impact of COVID-19 on Human Capital

Impact of COVID-19 on Wage Growth Rates

While the COVID-19 pandemic has had an immediate and devastating impact on all people and countries, the magnitude of its effects in the medium to long term is still unknown and complex because of its multidimensional effects. For instance, its harmful effects include but are not limited to wage growth losses resulting from the global economic recession, productivity losses of affected people, and interrupted education of the next generation of workers (particularly in low- and middle-income countries).

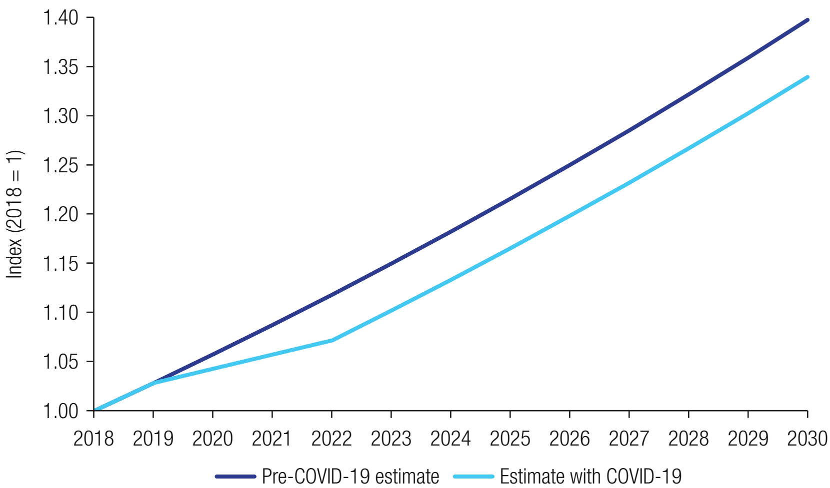
This section focuses on the impact of COVID-19 on only wage growth rates because all other impacts of COVID-19 on human capital are still limited to a few studies. Estimated labor income growth rates before COVID-19 are compared with estimates made in October 2020, when the pandemic was well under way (table 7.6). The COVID-19-related economic recession will cause a significant drop in the number of jobs, and it will take some time for employment to get back on track. Therefore, it is presumed that the COVID-19 recession has an effect on wages during the first three years of the pandemic, after which the annual wage growth rates will return to pre-COVID-19 levels (figure 7.5). Since human capital is estimated following the lifetime income approach, a drop in wage growth during the COVID-19 pandemic has a substantial impact on human capital through the discounted lifetime earnings to the base year.

TABLE 7.6 Annual Wage Growth Rates, Pre-COVID-19 and Post-COVID-19

Region	Countries	Wage growth pre-COVID-19 (%)	Wage growth post-COVID-19 (%)	Change (percentage points)
East Asia and Pacific, high-income	4	1.21	1.08	–0.13
East Asia and Pacific (excluding high-income)	11	4.00	4.00	0.00
Europe and Central Asia, high-income	27	1.21	1.08	–0.13
Europe and Central Asia (excluding high-income)	17	3.03	2.83	–0.20
Latin America and the Caribbean, high-income	4	1.21	1.08	–0.13
Latin America and the Caribbean (excluding high-income)	20	1.15	0.96	–0.19
Middle East and North Africa, high-income	7	1.21	1.08	–0.13
Middle East and North Africa (excluding high-income)	10	1.48	1.34	–0.14
North America	2	1.07	0.91	–0.16
South Asia	6	4.00	3.60	–0.40
Sub-Saharan Africa	38	2.31	1.41	–0.90
Total	**146**			

Source: World Bank staff calculations.
Note: All countries in North America are high-income; all countries in South Asia and Sub-Saharan Africa are low- or middle-income.

FIGURE 7.5 Index of the Wage Growth Trajectory: Impact of the COVID-19 Pandemic



Source: World Bank staff calculations.

Since the wage growth trajectory is affected only during the first three years of the pandemic, the changes in longer-term average wage growth rates are smaller, ranging from 0.13 percentage points in high-income countries to 0.9 percentage points in Sub-Saharan Africa. There is virtually no change in the long-term average wage growth rate in the middle-income East Asia and Pacific region, dominated by China.

At the global level, it is estimated that human capital declined about 1.9 percent in 2018 because of COVID-19, corresponding to US$14 trillion (in 2018 US dollars). At the global level, it is estimated that per capita human capital declined on average US$1,959 in 2018 because of COVID-19 (table 7.7). The most severely affected region is Sub-Saharan Africa, where per capita human capital declined by about 13.3 percent in 2018 (table 7.7; figure 7.6). The other most severely affected region is South Asia, where per capita human capital declined by about 6.3 percent in 2018. East Asia and Pacific is the least negatively affected region because only high-income countries in this region are badly affected by declining wage growth.

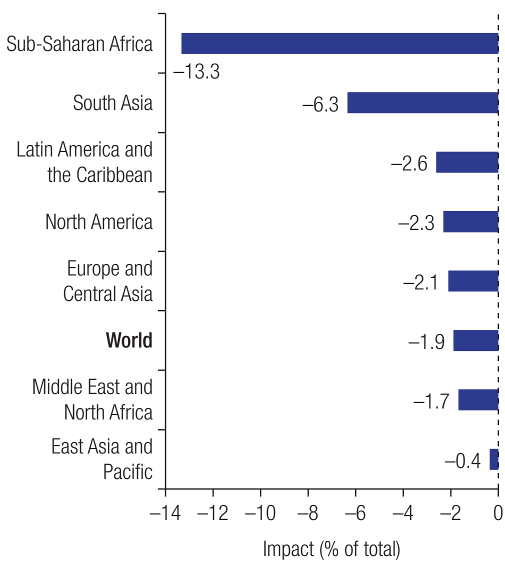
Looking at the change in human capital by income level, the results indicate that low-income (mostly Sub-Saharan African countries) and lower-middle-income countries (largely South Asian countries) are the most severely affected by the declining wage growth, while upper-middle-income countries are the least affected. In 2018, human capital per capita dropped by about 12.5 percent (US$821) in low-income countries and 5.6 percent (US$999) in lower-middle-income countries because of COVID-19. By contrast, the decline in per capita human capital in upper-middle-income countries is only about 0.8 percent (US$772).

TABLE 7.7 Drop in Per Capita Human Capital Because of COVID-19, by Income Group and Region
2018 US$

Income group and region	1995	2000	2005	2010	2015	2018
Income group						
Low-income	437	428	484	574	729	821
Lower-middle-income	425	464	563	751	898	999
Upper-middle-income	438	473	524	628	736	772
High-income: non-OECD	2,015	2,050	1,937	2,102	2,112	2,087
High-income: OECD	5,833	6,541	6,754	6,960	7,542	7,902
Region						
East Asia and Pacific	429	424	396	401	429	435
Europe and Central Asia	2,797	3,094	3,316	3,551	3,675	3,875
Latin America and the Caribbean	1,232	1,350	1,390	1,541	1,742	1,792
Middle East and North Africa	491	487	482	543	548	529
North America	10,534	12,066	12,500	12,679	13,894	14,530
South Asia	408	489	594	693	852	1,001
Sub-Saharan Africa	1,172	1,048	1,152	1,617	1,853	1,888
World	**1,428**	**1,540**	**1,596**	**1,712**	**1,869**	**1,959**

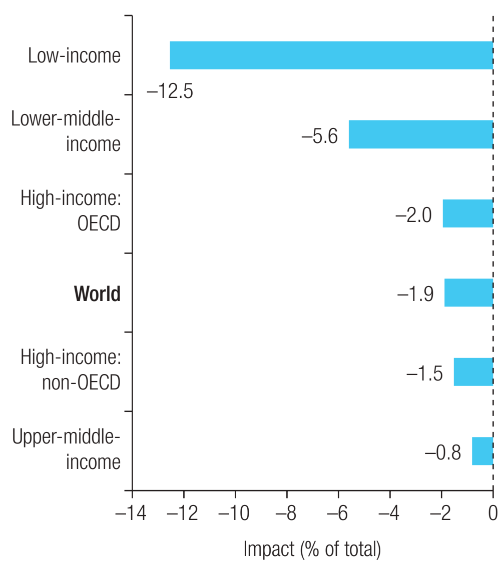
Source: World Bank staff calculations.
Note: Since human capital is estimated following the lifetime income approach, a drop in wage growth during the COVID-19 pandemic has a substantial impact on human capital through the discounted lifetime earnings to the base year. OECD = Organisation for Economic Co-operation and Development.

FIGURE 7.6 Impact of COVID-19 on Human Capital, by Region, 2018



Source: World Bank staff calculations.
Note: Since human capital is estimated following the lifetime income approach, a drop in wage growth during the COVID-19 pandemic has a substantial impact on human capital through the discounted lifetime earnings to the base year.

FIGURE 7.7 Impact of COVID-19 on Human Capital, by Income Group, 2018



Source: World Bank staff calculations.
Note: Since human capital is estimated following the lifetime income approach, a drop in wage growth during the COVID-19 pandemic has a substantial impact on human capital through the discounted lifetime earnings to the base year. OECD = Organisation for Economic Co-operation and Development.

For high-income OECD countries, the decline in per capita human capital is about 2 percent, although these countries are estimated to experience an average decline of US$7,902 in 2018 (table 7.7; figure 7.7).

Conclusion

This chapter provided a set of comparable estimates of human capital based on a time series of household surveys for 146 countries throughout 1995–2018. Human capital accounts for about two-thirds of total global wealth and typically a higher share in upper-middle-income and high-income OECD countries. On average, the share of human capital increases with higher levels of development and is highest in high-income and upper-middle-income countries.

Estimates by gender demonstrate the continued, significant disparity between men's and women's human capital, which is greater in some regions than others. Globally, the female share in human capital is only about one-third, and progress in closing the gender gap has been slow over the past 25 years. The COVID-19 pandemic and economic shutdown have had disproportionate impacts on women and may have set back progress toward gender equality even further.

The COVID-19 pandemic has clearly created immediate impacts on economic growth, jobs, and wages. Medium- to long-term effects on human capital resulting from the interrupted education of millions of students and negatively affected health of millions of people are still limited to a few studies (box 7.3). The partial impacts estimated for the

BOX 7.3 Impact of the COVID-19 Pandemic on Education and Health

The COVID-19 pandemic is of critical concern for human capital through tragic direct channels of health (mortality and morbidity) and indirect channels of household income, productivity, educational quality, health, and economywide impacts. Simulations conducted for the Human Capital Index 2020 Update (World Bank 2020) suggest that school closures combined with family hardship are significantly affecting the accumulation of human capital for the current generation of school-age children. Additionally, COVID-19's disruption of health services, losses in income, and worsened nutrition are expected to increase child mortality and stunting, with effects that will be felt for decades to come.

A recent paper by Azevedo et al. (2020) estimates that the potential short- and long-term impacts of school closures and remote learning could result in a loss of between 0.3 and 0.9 year of schooling adjusted for quality.

Roberton et al. (2020) estimate the additional maternal and under-5 child deaths stemming from the potential health systems disruption and worsened access to food because of COVID-19 in 118 low- and middle-income countries under two scenarios. The optimistic scenario suggests that COVID-19 will increase maternal deaths by 8.3 percent and child deaths by 9.8 percent, while the pessimistic scenario suggests that maternal deaths will increase by 38.6 percent and child deaths will increase by 44.7 percent.

short-term economic shutdown could be devastating, particularly for low- and middle-income countries, setting back gains in eradicating poverty. In addition, according to a recent report by UNESCO and the World Bank (2021), two-thirds of low-income and lower-middle-income countries have cut their education budgets since the onset of the COVID-19 pandemic. Moreover, there is a potential that the cuts will be higher in the future (UNESCO and World Bank 2021). The cuts in education budgets in low-income and lower-middle-income countries may further depress the value of human capital for those countries in the future.

The focus in this chapter was solely on human capital as a productive asset that produces a stream of benefits: future wages. This is not to deny that education, good health, and knowledge are sources of well-being in and of themselves, or that doing a job well is one of the great human pleasures. Development is about building human capital—some of that requires direct investment, such as education, while some requires broader investment in a healthy environment, water, sanitation, and clean air.

In future work, some improvements to the methodology used here could be undertaken, including the number of surveys needed and the methodology on filling gaps between surveys. In addition, the impact of COVID-19 on education and health can be incorporated into the methodology, and more precise estimates on the impact of COVID-19 could be made. Further research and analysis on the factors driving the large differences between men's and women's human capital are also important, especially for policy makers. Nevertheless, even with the data now available, additional analysis as well as simulations can be undertaken to inform policy.

Annex 7A: Methodology for Calculating Human Capital: Estimating Human Capital with the Lifetime Income Approach

Annex 7A explains how the lifetime income approach developed by Jorgenson and Fraumeni (1989, 1992a, 1992b) was implemented to estimate human capital. According to this approach, human capital is estimated as the total present value of the expected future labor income that could be generated over the lifetime of the women and men currently living in a country (Fraumeni 2008; Hamilton and Liu 2014).

The implementation of the lifetime income approach requires data by age and gender on population, employment and labor force participation, education, earnings profiles, and survival rates. The data sources for each variable are included in table 7A.1. The estimation is carried out in seven steps, as described in this annex.

In the equations, the country and gender dimensions of variables are omitted for ease of presentation.

Step 1. Estimating the Earnings Regressions

The World Bank's International Income Distribution Database (I2D2), a unique database of more than 2,000 household surveys maintained by the World Bank, is used to construct a database containing information on the number of people, their age, gender, earnings, educational attainment,

TABLE 7A.1 Data Sources for the Human Capital Calculations

Indicator or variable	Data source(s)	Notes
Annual earnings	I2D2	Annual earnings are calculated utilizing the Mincerian regression results. The (relative) earnings profile by age, education, and gender is derived for each country and year given the corresponding data availability.
Educational attainment	I2D2	Years of education by age and gender are derived for each country and year.
Employment rates	I2D2	The employment rate and self-employment rate by age, gender, and education level are calculated for each country and year. These rates are calculated for employed (or self-employed) persons divided by the whole population, which includes the employed, self-employed, unemployed, and the people out of the labor force.
School enrollment rates	I2D2	This indicates whether an individual by age, gender, and education is enrolled in school or not; used for the probability of remaining employed in future years.
Employment	ILO	The ILO employment data are used as control totals for scaling up employment from the I2D2 database. ILO employment data are also used for filling data gaps when necessary.
Compensation of employees, GDP	United Nations National Accounts database	The Compensation of Employees data are used as input to control totals for scaling up annual earnings estimates from the I2D2 database and for filling the data gaps. In addition, the GDP data are used for expressing variables as a percentage of GDP.
Labor share of earnings of the self-employed	Penn World Table database	Penn World Table estimates of the labor component of the earnings of the self-employed in total earnings of the self-employed. Used as input to control total labor earnings.
Total labor earnings	United Nations National Accounts database and Penn World Table database	Compensation of employees plus labor earnings of the self-employed. This combined labor earnings estimate is used as a control total for scaling up earnings estimates from I2D2 to the national level.
Population	United Nations World Population Prospects	By gender and age groups: The distribution of workers from the I2D2 database is scaled up using the population data.
Survival rates	GBD study from the Institute for Health Metrics and Evaluation	Survival rates are calculated utilizing the death rates obtained from the GBD study. The GBD database includes global, regional, and national age- and gender-specific mortality for 369 diseases and injuries in 204 countries and territories.

Source: World Bank.
Note: GBD = Global Burden of Disease; GDP = gross domestic product; I2D2 = International Income Distribution Database; ILO = International Labour Organization.

school enrollment rates, and employment rates. This database is used to estimate the Mincerian coefficients. The Mincerian wage regressions are estimated as

$$Ln(w_i) = \alpha + \beta_1 e_i + \beta_2 X_i + \beta_3 X_i^2 + \mu_i \,, \tag{7A.1}$$

where $Ln(w_i)$ is the natural log of earnings of individual i, e_i is years of schooling (from 0 to 24), X_i is labor market working experience (estimated as AGE_i (from age 15 to 64) $- e_i - 6$), X_i^2 is working experience-squared, and μ_i is a random disturbance term reflecting unobserved abilities. The coefficient β_1 measures the return to an extra year of schooling, and the coefficients β_2 and β_3 measure the return to working experience. Since working experience shows a decreasing marginal return, in general the coefficient β_3 is expected to be a negative value. The constant, α, measures the average log earnings of individuals with zero years of schooling and working experience. Equation (7A.1) is estimated for each economy for each survey year for males and females separately.

Although the I2D2 includes the number of years of schooling for most countries, some countries have data on levels of education instead of number of years of schooling. Therefore, a conversion is needed to estimate the Mincerian coefficients. In this case, including the levels of education as dummy variables in the Mincerian equation, the Mincerian coefficients are estimated for each level of education. For example, if a country's schooling data are represented as primary, secondary, and tertiary, equation (7A.1) is converted to the following form,

$$Ln(w_i) = \alpha + \beta_{1p}e_{ip} + \beta_{1s}e_{is} + \beta_{1t}e_{it} + \beta_2 X_i + \beta_3 X_i^2 + \mu_i\,, \qquad (7A.2)$$

where the subscripts p, s, and t represent the levels of education (primary, secondary, and tertiary). Hence, the private rate of return to different levels of schooling (r) can be derived from the following equations:

$$r_p = \beta_{1p} S_p, \qquad (7A.3)$$

$$r_S = (\beta_{1s} - \beta_{1p}) \,/\, (S_s - S_p), \qquad (7A.4)$$

$$r_t = (\beta_{1t} - \beta_{1s}) \,/\, (S_t - S_s), \qquad (7A.5)$$

where S_p, S_s, and S_t stand for the total number of years of schooling for each successive level.

The wages/earnings profile by age, education, and gender, $AIN_{s,a,e}$, can be readily derived for each economy-year using the following equation:

$$AIN_{s,a,e} = \exp(\alpha + \beta_1 e + (\beta_2 + \beta_3\, X_{s,a,e})X_{s,a,e}). \qquad (7A.6)$$

Based on the results of the Mincerian regressions, a matrix of expected earnings, H, is constructed. Each cell in the matrix accounts for labor earnings of the population age a, gender s, and education level e. If $n_{s,a,e}$ is the number of workers of age a, gender s, and years of schooling e, each cell in the matrix is defined as

$$H_{s,a,e} = n_{s,a,e} AIN_{s,a,e}. \qquad (7A.7)$$

Step 2. Scaling Up Earnings and Estimating Labor Earnings of the Self-Employed

For the calculation of human capital, total earnings should include not only wages but also the value of any additional benefits provided to employees, such as social security payments, health insurance, housing, or other benefits in cash or in-kind. The earnings profiles from the surveys represent an underestimate of total earnings because they include only wages and not any additional benefits. To adjust for this underestimate, Compensation of Employees from the System of National Accounts (SNA) is used to benchmark survey earnings profiles. In this approach, the relative wages from the surveys matter rather than the absolute level values.

However, there is one more step needed to include all human capital. Total labor income consists of two components: the incomes of the employed and the self-employed. The earnings of employed workers are included in the SNA under Compensation of Employees. The earnings of the self-employed are included in the SNA under Mixed Income or a more general category, Gross Operating Surplus, which includes all incomes not accruing to employees, mostly returns to capital and natural resources. The estimation of each component and how it is used to benchmark survey earnings profiles are discussed in this section.

Earnings of Employees

The household surveys used for the computation of the earnings profiles—as well as the probability of working—are nationally representative. The surveys are in most cases of good quality, but they may still generate estimates that are not consistent with the Compensation of Employees in the SNA (EC et al. 2009). Compensation of Employees includes the economic value of benefits, such as housing or health insurance, in addition to wages, but household surveys typically report only the wages received, thus underestimating total compensation. In some countries, additional benefits, in cash or in-kind, can be substantial. Total earnings from the survey, and the resultant human capital, are expected to be too low in comparison with the share of labor earnings in gross domestic product (GDP) because they do not include other benefits. This is addressed by using Compensation of Employees as part of the control total to scale up earnings profiles from the surveys.

Estimating the Labor Income of the Self-Employed

The economic role of the self-employed can be especially important in many low- and middle-income countries, where subsistence agriculture and the informal economy are very common. However, the earnings of the self-employed are not well represented in the national accounts of many countries because, with few exceptions, Compensation of Employees includes only workers who are formally employed. The earnings of the self-employed are included as part of another category, Mixed Income or Gross Operating Surplus, which also includes income accruing to produced capital and natural resources (resource rents). Earnings of the self-employed workers may also be poorly represented in household surveys.

Correcting this omission requires (1) identifying the earnings that can be attributed to the self-employed and (2) distinguishing the labor component of earnings from returns to other factors of production, which are all combined. For human capital estimates, only the labor portion of the earnings of the self-employed should be included. The Penn World Table (PWT) database has made estimates of the labor component of the income of the self-employed (Feenstra, Inklaar, and Timmer 2015), which is described in the following text.

For the purpose of disaggregating earnings by employment, shares of labor income of employees and self-employed from the PWT data on total compensation of labor are used, except for China, for which the income group average is used.[1] The PWT data on total compensation of labor construct a "best estimate" labor share based on four options for adjustment, to estimate the shares of labor income of employees and the self-employed.

The first two adjustment estimation methods proposed by the PWT are used for the roughly 60 countries that report mixed income as a separate income category in the national accounts. Mixed income isolates total income earned by self-employed workers from resource rents and returns to produced capital by other producers. Mixed income combines capital and labor income accruing to the self-employed and can be considered as an upper bound of the amount of labor income earned by the self-employed. The two adjustment methods are as follows:

1. All mixed income is allocated to labor assuming self-employed workers use only labor input.
2. Half of the mixed income is allocated to labor assuming self-employed workers use labor and capital in the same proportion.

The third adjustment method assumes the self-employed earn the same average wage as employees. However, this method has some drawbacks for countries where the share of employees in the labor force is low. Assuming that the self-employed earn the same average wage as employees will overstate the labor income of the self-employed in those countries. In particular, agriculture employs about half of the self-employed in most low-income countries. This leads to the fourth adjustment method, which is based on the share of agriculture in GDP. Total value added in agriculture is considered a good enough proxy for the labor earnings of the self-employed.

As explained, all four methods have some drawbacks, and therefore the PWT data on total compensation of labor construct a "best estimate" labor share. Adjustments based on mixed income are applied where available because the mixed income captures the income of the self-employed. The second adjustment method is preferable since the first adjustment method assumes no use of produced capital by the self-employed. The third and fourth adjustment methods are used if there is no mixed income data and the share of labor compensation of employees is below 0.7.

Total Labor Earnings

The PWT-estimated labor component of the earnings of the self-employed is added to Compensation of Employees to produce the control total for total labor earnings to scale up survey-derived earnings profiles by age, gender, and years of education. This approach implicitly assumes that the demographic and earnings profiles of the self-employed are the same as those of employed workers in formal labor markets. Although this is a highly simplified approach, there are insufficient data with global coverage to refine treatment of the self-employed at this time.

The total labor compensation (W) consists of two parts: ($comp\_employ$) plus ($comp\_self$). By using the PWT data, it can be calculated as follows:

$$W = comp_{employ} + comp_{self} = LABSH * GDP, \tag{7A.8}$$

$$comp_{employ} = LABSH_{employ} * GDP, \tag{7A.9}$$

$$comp_{self} = LABSH_{self} * GDP, \tag{7A.10}$$

where $LABSH$,[2] $LABSH_{employ}$, and $LABSH_{self}$ represent the total labor share (including employees and the self-employed), labor share of employees, and labor share of the self-employed, respectively. Therefore, $comp_{employ}$ and $comp_{self}$ stand for total compensation of employees and the self-employed, respectively.

The annual labor income ($AIN_{s,a,e}$) is assumed to be the same for employees and the self-employed and is estimated by using information for employees in the I2D2 database (equation 7A.6). Then the following adjustment can be made:

$$\sum_{s,a,e} \left[\overline{AIN}_{s,a,e} * n_{s,a,e} \right] = W, \tag{7A.11}$$

where $n_{s,a,e}$, as before, includes the number of people for employees and the self-employed, and $\overline{AIN}_{s,a,e}$ is the after-adjustment annual income. $\overline{AIN}_{s,a,e}$ is estimated as follows:

$$\overline{AIN}_{s,a,e} = \frac{W}{\sum_{s,a,e} \left[AIN_{s,a,e} * n_{s,a,e} \right]} * AIN_{s,a,e}. \tag{7A.12}$$

After the lifetime income ($h_{s,a,e}$) for each cell (by gender s, age a, and education e) has been derived (as described in step 6), the I2D2 sample share of the self-employed can be applied to the corresponding population data to generate the human capital for the self-employed.

In other words, the human capital for the total employed (employees plus self-employed) is calculated first by using the adjusted annual income profiles as shown in equation (7A.12). Then among the calculated total human capital, the part contributed by the self-employed can be separately estimated.

Step 3. Filling the Data Gaps

Since the estimations rely on labor force and household surveys, it is important to have at least one survey for each year and each country. Unfortunately, this is not the case for most countries. Moreover, some countries have only one survey for the entire period (table 7A.2). Therefore, filling the data gaps is a crucial step for the human capital calculations. Although the current method for filling the gap has some drawbacks, it is useful.

To fill the data gaps, the estimated Mincer parameters and I2D2 sample employment and enrollment rates for the survey year are held constant until the next available survey year, and control totals for earnings for each of the intervening years are used to generate the human capital estimates for the years between two survey years. For example, if there exists only one survey for a country, the parameters of this one survey are used for the entire period. If there exist three surveys (for example, 1995, 2000, and 2010) for 1995–2018, the parameters from 1995 are used for 1995–99, the parameters from 2000 are used for 2000–2009, and the parameters from 2010 are used for 2010 and onward.

Obviously, there are significant problems associated with this method. First, an occasional jump occurs between human capital estimates from a nonsurvey year to a survey year. For example, if there are surveys for 1995 and 2010, all the data gaps until 2009 are filled with the parameters from the 1995 survey. A jump could occur between the human capital estimates of 2009 to 2010. In addition, if there is only one survey, all the periods must be estimated with the data from one survey, and this does not allow policy makers to see the effects of policy changes, if any.

TABLE 7A.2 Number of I2D2 Surveys among Countries

Survey count	Countries
1	29
2	15
3	12
4	14
5	5
6	7
7	6
8	3
9–11	8
12	11
13	15
14–19	10
20 or more	11
Total	**146**

Source: World Bank.
Note: I2D2 = International Income Distribution Database.

Step 4. Scaling Up the Employment and Population

Since the survey data do not capture the entire population, the data from the surveys are adjusted to population estimates from the United Nations to ensure that the estimates are adequate.

If $n_{s,a,e}$ is the number of workers age a, gender s, and years of schooling e, and P is the total population of a country from the United Nations World Population Prospects, the scale parameter a is calculated as

$$\alpha = \frac{P}{\sum_{s,a,e}\left[n_{s,a,e}\right]}. \tag{7A.13}$$

Thus, the scaled number of workers age a, gender s, and years of schooling e, $N_{s,a,e}$, is calculated as

$$N_{s,a,e} = \alpha * [n_{s,a,e}]. \tag{7A.14}$$

Step 5. Calculating Survival Rates for Each Country

Survival rates utilize death rates obtained from the Global Burden of Disease Study (GBD).[3] The GBD database includes global, regional, and national age- and gender-specific mortality for 369 diseases and injuries in 204 countries and territories for 1990–2019. Survival rates are calculated as

$$v_{a+1} = 1 - death_a, \tag{7A.15}$$

where v_{a+1} is the probability of surviving one more year at age a, and $death_a$ is the death rate at age a. Equation (7A.15) is calculated for each country for each survey year for males and females separately.

Step 6. Calculating Lifetime Income

Two stages in the life cycle of an individual of working age are distinguished: ages 15–24 and ages 25–65. The main assumption here is that individuals ages 15–24 have the possibility to receive further education, while those ages 25–65 are assumed to have no such possibility. Based on this assumption, the lifetime labor income of an individual is calculated as follows:

- Persons ages 25–65

$$h_{s,a,e} = p^m_{s,a,e} w^m_{s,a,e} + p^s_{s,a,e} w^s_{s,a,e} + \left[\frac{1+g}{1+d}\right] * v_{s,a+1} * h_{s,a+1,e} \tag{7A.16}$$

- Persons ages 15–24

$$h_{s,a,e} = p^{m}_{s,a,e} w^{m}_{s,a,e} + p^{s}_{s,a,e} w^{s}_{s,a,e} + \left(1 - r^{e+1}_{s,a,e}\right) * \left[\frac{1+g}{1+d}\right] * v_{s,a+1} * h_{s,a+1,e}$$
$$+ r^{e+1}_{s,a,e} * \left[\frac{1+g}{1+d}\right] * v_{s,a+1} * h_{s,a+1,e+1} . \qquad (7A.17)$$

In these equations $h_{s,a,e}$ is the present value of the lifetime income for an individual age a, gender s, and education e, $p^{m}_{s,a,e}$ is the probability to be employed, $w^{m}_{s,a,e}$ is the received compensation of employees when employed, $p^{s}_{s,a,e}$ is the probability to be self-employed, $w^{s}_{s,a,e}$ is the received compensation of employees when self-employed, $r^{e+1}_{s,a,e}$ is the school enrollment rate for taking one more year of education from education e to one year higher level of e+1, d is the discount rate, g is the annual wage growth rate, and $v_{s,a+1}$ is the probability of surviving one more year.

Equations (7A.16) and (7A.17) suggest that the lifetime income of a representative individual consists of the current labor income and the lifetime income in the next year. The current labor income is adjusted by the probabilities of being employed or self-employed, and the lifetime income in the next year is adjusted by a discount factor and the corresponding survival rate. In addition, for an individual age 15–24, there are two courses of action: first, holding the same education level and continuing to work, and second, taking one more year of education and earning income after completing the education.

The probabilities of being employed ($p^{m}_{s,a,e}$) or self-employed ($p^{s}_{s,a,e}$) can be approximated by the employment rate or self-employment rate for people age a, gender s, and education e. These rates have to be calculated by the employed (or self-employed) persons divided by the entire population that includes the employed, self-employed, unemployed, and people out of the labor force. The sample ratios from the I2D2 database are used.

The empirical implementation of equations (7A.16) and (7A.17) is based on backward recursion. This suggests that the lifetime labor income of a representative individual age 65 is zero since it is presumed that there is no working life after age 65. Therefore, the lifetime labor income of a person age 64 is her current labor income. Likewise, the lifetime labor income of a representative individual age 63 is the sum of her current labor income and the present value of the lifetime labor income of a person age 64. Hence, the present value of the lifetime income matrix is created for an economy by applying backward recursion to equations (7A.16) and (7A.17).

Human capital is calculated under the assumption that labor earnings grow at a constant rate g over the working lifetime. Because of the efficiency differences among the income groups and regions, region- and income group–specific annual real labor earnings growth rates are applied. The growth rates are derived from the World Bank's macroeconomic and fiscal model based on historical data and long-term projections based on potential output in each country, which builds on total factor productivity growth, capital stocks, and employment growth. In addition, average long-term wage growth rates are capped at 4 percent. Furthermore, it is assumed

TABLE 7A.3 Labor Income Growth Rates, by Region and Income Level

Region	Countries	Wage growth (%)
East Asia and Pacific, high-income	4	1.08
East Asia and Pacific (excluding high-income)	11	4.00
Europe and Central Asia, high-income	27	1.08
Europe and Central Asia (excluding high-income)	17	2.83
Latin America and the Caribbean, high-income	4	1.08
Latin America and the Caribbean (excluding high-income)	20	0.96
Middle East and North Africa, high-income	7	1.08
Middle East and North Africa (excluding high-income)	10	1.34
North America	2	0.91
South Asia	6	3.60
Sub-Saharan Africa	38	1.41
Total	**146**	

Source: World Bank staff calculations.

that real labor wage growth rates are constant over time during the lifetime.

In addition, labor income growth for 2020–22 is revised down to adjust for the short-run effects of the COVID-19 pandemic on wages. For the period after 2023, a recovery in the labor income growth rates is assumed to be aligned with the recovery in total factor productivity growth. The growth rates for labor income used in the human capital calculations are provided in table 7A.3.

In addition, in calculating the net present value, a uniform discount rate of 4 percent is used for human capital in line with all resources and countries within the wealth accounting framework.

Step 7. Generating the Lifetime Income for All People in an Economy

The calculations from step 1 to step 6 generate the lifetime income profiles for a representative individual cross-classified by age, gender, and education. The lifetime income profiles for a representative individual are multiplied by the corresponding number of people in a country, and thus the human capital stock by age, gender, and education is calculated.

Summing up the stocks of human capital across all classified categories generates the estimate of the aggregate value of the human capital stock for each country:

$$HC = \Sigma_{s,a,e}[h_{s,a,e}] * pop_{s,a,e}, \tag{7A.18}$$

where HC is the human capital stock, $h_{s,a,e}$ is the present value of the lifetime income for an individual age a, gender s, and education e, and $pop_{s,a,e}$ is the population of age a, gender s, and education level e.

Notes

1. Official data on labor income for China include income of employed and self-employed workers.
2. The LABSH variable in the PWT is expressed as a share of GDP at basic prices. Therefore, when incorporated in the human capital calculations, LABSH is multiplied by an adjustment factor, reflecting the ratio of GDP at basic prices to GDP at market prices. Thus, the resulting LABSH is expressed as a share of GDP at market prices and used accordingly in equations 7A.8 to 7A.10.
3. The Global Burden of Disease Study 2019 database is used for the human capital calculations. http://www.healthdata.org/gbd/2019.

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8

Impact of Air Pollution on Human Capital

Kenan Karakulah, Glenn-Marie Lange, Yewande Awe, and Shun Chonabayashi

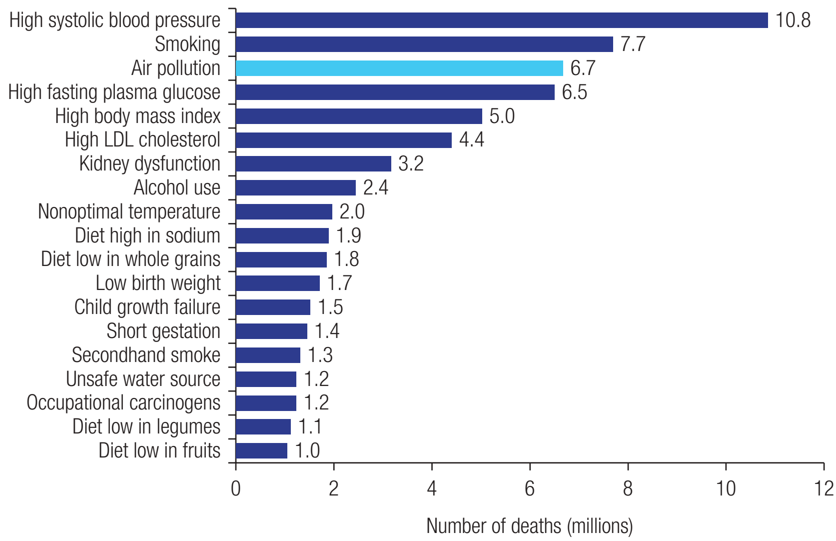
Main Messages

- In 2019, outdoor and household air pollution jointly accounted for 6.7 million premature deaths globally. The majority of these were caused by human exposure to fine inhalable particles or fine particulate matter, also known as $PM_{2.5}$. While noting that no safe level of exposure to air pollution exists, analysis shows that at the global level, per capita human capital would have increased by about US$290 in 2018 if there were no premature deaths from air pollution.
- At the regional level, the loss of human capital resulting from premature deaths attributable to air pollution ranged from 0.1 percent in North America and Europe and Central Asia to 1.4 percent in South Asia in 2018. The impact was higher in low-income and lower-middle-income countries than in high-income countries.

Introduction

Air pollution is one of the world's leading risk factors for health and the cause of illness and premature death from diseases such as lung cancer, ischemic heart disease, chronic obstructive pulmonary disease, stroke, and pneumonia. In this analysis, air pollution includes ambient particulate matter with a diameter of less than 2.5 microns ($PM_{2.5}$), household $PM_{2.5}$ from the burning of solid fuels, and ambient ozone pollution. In 2019, air pollution was responsible for 6.7 million deaths globally, which accounted for about 11.8 percent of total deaths that year. Following high systolic blood pressure and smoking, air pollution was the third leading risk factor for death in 2019 (figure 8.1).

FIGURE 8.1 Global Number of Deaths, by Risk Factor, 2019



Source: GBD Collaborative Network 2020.
Note: The figure includes only risk factors that were attributed to more than 1 million deaths in 2019. Air pollution includes ambient particulate matter pollution, household air pollution from solid fuels, and ambient ozone pollution. LDL = low-density lipoprotein.

The majority of deaths related to air pollution are caused by human exposure to fine inhalable particles or fine particulate matter of 2.5 microns or less in diameter ($PM_{2.5}$) (see box 8.1). As shown in figure 8.2, outdoor air pollution in cities and rural areas was estimated to cause some 4.1 million premature deaths globally in 2019. The combination of declining air quality, increasing rates of urbanization, and population aging has contributed to a rise in the number of deaths from ambient $PM_{2.5}$ each year. Household air pollution from solid fuels was the leading risk factor for premature deaths from exposure to air pollution until 2009. However, the number of premature deaths resulting from household air pollution from solid fuels has been constantly decreasing, while premature deaths from ambient $PM_{2.5}$ have been increasing. Household air pollution from solid fuels was estimated to cause about 2.3 million premature deaths globally in 2019, while ambient ozone pollution was estimated to cause about 0.4 million premature deaths globally in 2019.

Map 8.1 illustrates disability-adjusted life years (DALYs) attributable to air pollution by country.[1] The share of DALYs attributable to air pollution is quite high in South Asia, East Asia, Sub-Saharan Africa, the Middle East and North Africa, and the Balkans, while it is quite low in North America, Northern Europe, and Western Europe. According to Gordon et al. (2017), the people who are most affected by air pollution are children and the elderly, particularly in low- and middle-income countries.

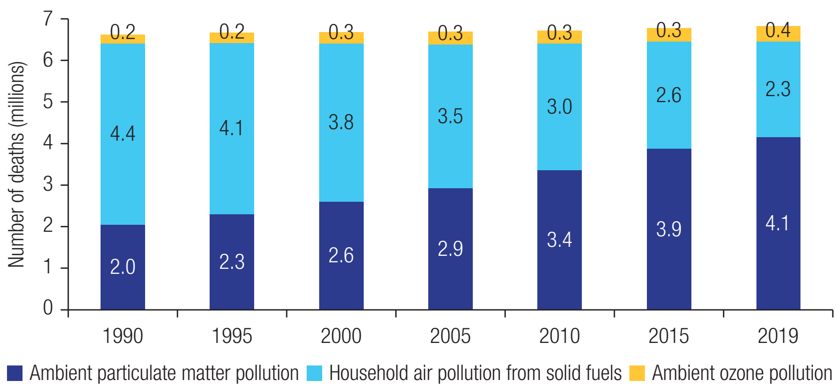
BOX 8.1 Toxicity of Fine Particulate Matter Air Pollution Varies According to Its Source and Chemical Composition

Inhalable, fine particles, also known as $PM_{2.5}$, are the most detrimental air pollutants to human health. $PM_{2.5}$ comes from both natural and anthropogenic origins: in the former case, for example, desert dust or sea spray, and in the latter case, burning of fossil fuels, transport, burning of agricultural residues, or solid fuels. Most deaths that are attributed to outdoor $PM_{2.5}$ air pollution globally are caused by cardiovascular disease. Global estimates of the health burden of air pollution typically assume that all $PM_{2.5}$ particles are equally toxic. In other words, no distinction is made between $PM_{2.5}$ from different sources or between the chemical species present in $PM_{2.5}$ mass. Particles in low- and middle-income countries usually have very different sources and compositions from particles in high-income countries. Therefore, the health effects per unit mass of $PM_{2.5}$ are likely different in low- and middle-income countries from those in high-income countries, which form the basis of present global and regional assessments of health impacts (Thurston et al. 2021).

Recent analytical work by the World Bank shows that the toxicity of $PM_{2.5}$ is dependent on the source and chemical constituents or species of the $PM_{2.5}$ particles (Thurston et al. 2021). Trace constituents from $PM_{2.5}$ and $PM_{2.5}$ mass from fossil fuel combustion are among the greatest contributors to $PM_{2.5}$ toxicity. Of the fossil fuel combustion particles, coal- and traffic-related $PM_{2.5}$ were found to be most consistently associated with cardiovascular mortality, especially ischemic heart disease or heart attacks, as a result of short- and long-term exposure to $PM_{2.5}$ particles. Notably, sulfate or particulate sulfur (a trace constituent of $PM_{2.5}$ and a marker of coal burning) is among the most, if not the most, important constituents of $PM_{2.5}$ associated with additional hospital admissions and mortality. Overall, the cardiovascular disease risks of sulfate, elemental carbon (another trace constituent of $PM_{2.5}$ and a marker of diesel-fueled vehicle emissions), and $PM_{2.5}$ from coal combustion are larger than that of $PM_{2.5}$ mass in general. The targeting of these sources (coal burning and diesel-fueled vehicles) as a matter of priority in World Bank client countries has important implications for reducing premature death and morbidity and the associated damage to human capital in low- and middle-income countries. Ambient air pollution control efforts in low- and middle-income countries need to account for the contributing sources of $PM_{2.5}$ and the toxicity of the $PM_{2.5}$ from each source category. Reducing pollution from these sources can be expected to return greater cardiovascular disease health benefits per unit mass of $PM_{2.5}$ reduced than if $PM_{2.5}$ mass continues to be addressed equally, irrespective of source and composition.

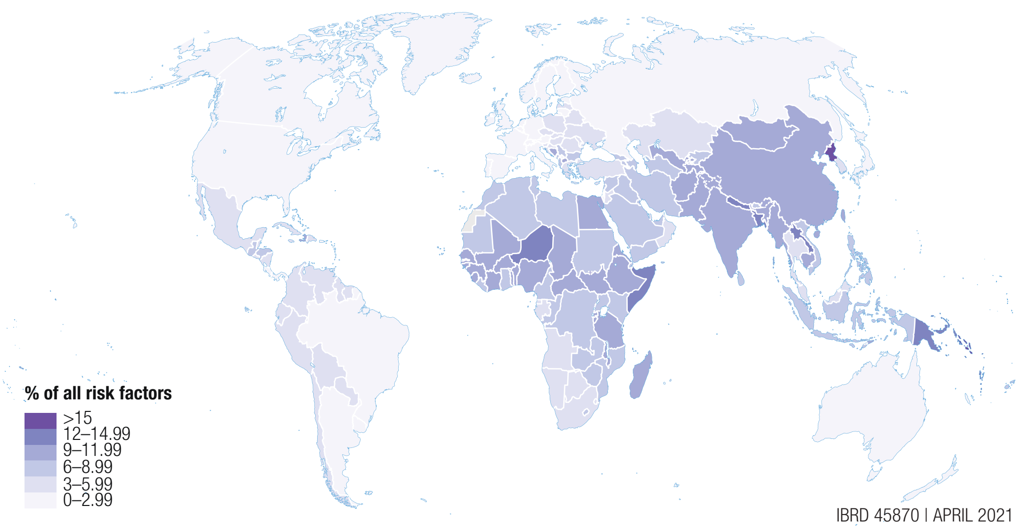
With respect to $PM_{2.5}$ of natural origins, a separate World Bank report finds that there is evidence of an association between long-term exposure to dust and its markers and cardiovascular and respiratory mortality (Ostro, Awe, and Sánchez-Triana 2021). Although the association is not as strong as those observed for sulfate and elemental carbon, the findings indicate that absent further evidence, it is reasonable to assume that the health risk per microgram of natural dust is generally similar to that of the constituents of particulate matter, with the exceptions of sulfate and elemental carbon.

FIGURE 8.2 Global Number of Deaths from Air Pollution, 1990–2019



Source: GBD Collaborative Network 2020.

MAP 8.1 Disability-Adjusted Life Years (DALYs) Attributable to Air Pollution



Source: GBD Collaborative Network 2020.

The adverse effects of air pollution on human capital include premature mortality and ill health (morbidity), which affect labor productivity and economic growth (India State-Level Disease Burden Initiative Air Pollution Collaborators 2020). The potential impacts of air pollution are wide-ranging, including but not limited to deaths from carbon monoxide poisoning and respiratory and heart-related health problems stemming from pollution exposure, damaging children's health and survival, diminishing labor productivity because of worsening cognitive performance, and reducing students' ability to benefit from education (Lavy, Ebenstein, and Roth 2014; Shehab and Pope 2019; Zhang, Chen, and Zhang 2018).

Estimates of premature mortality have been made by the Global Burden of Disease Study (noting some caveats, see box 8.2), and the benefits of reducing premature mortality can be calculated. But calculating the impact on morbidity and the benefits from reducing air pollution for human capital is more challenging. First, it is challenging to measure the precise effects of air pollution on labor productivity and cognitive performance although the deaths stemming from air pollution are observable. In addition, deaths caused by air pollution can take place in different time periods depending on the form and impact of the air pollution. While an intense carbon monoxide intake could cause a sudden death, persistent exposure to low levels of carbon monoxide could cause death in months or years. The available global data do not include information on the duration of exposure to air pollution before death occurs. Furthermore, the literature documenting the effects of air pollution on human productivity

BOX 8.2 Challenges in Estimating Global Mortality Attributable to Air Pollution

Notwithstanding that it is well known that $PM_{2.5}$ is the most detrimental air pollutant to human health, there are significant uncertainties that remain to be addressed in estimating global mortality attributable to air pollution. Among the most important is the extrapolation of the integrated exposure-response function, based primarily on studies in Europe and North America, to the rest of the world where the mixture and concentrations of $PM_{2.5}$ are very different. Another major uncertainty is the question of the toxicity of blowing dust. Clearly, for specific countries and regions, the treatment of the toxicity of dust can have an important impact on the mortality estimates.

A recent World Bank report assessed the methodological aspects underlying changing the Global Burden of Disease estimates for ambient air pollution. The report found that while there have been significant improvements, notably in exposure methodology, the lack of ground-level air quality monitors in several regions—the Middle East and North Africa, Sub-Saharan Africa, and South Asia—has resulted in poorer predictions of $PM_{2.5}$ relative to other regions (Ostro et al. 2018).

In regions where air quality data obtained from ground-level monitors are not available, global estimates of the mortality burden of ambient air pollution have used satellite-derived measurements to predict ambient ground-level concentrations of $PM_{2.5}$. Satellite-derived measurements have been used successfully in regions such as Europe, North America, and Organisation for Economic Co-operation and Development countries, where established and strong air quality monitoring networks exist for calibrating satellite measurements. However, based on selected pilot studies in nine cities in low- and middle-income countries, separate World Bank analytical work found that the use of satellite-derived measurements for predicting ambient air quality is not reliable. The measurements resulted in large errors, ranging from 21 to 85 percent in satellite-based estimates of daily average $PM_{2.5}$ concentrations at a given location in a city (Alvarado et al. 2019; World Bank 2021a).

is limited. This chapter reflects only the direct effect of air pollution on premature mortality, because of limited data on productivity impacts.

This chapter builds on chapter 9 in the 2018 edition of *The Changing Wealth of Nations* (Lange, Wodon, and Carey 2018), which provided a measure of the loss, or depreciation, of human capital associated with premature deaths from exposure to air pollution. The previous work informed the treatment of air pollution–related damage in the measurement of adjusted net saving, but it noted that future work would need to address the impact of air pollution on human capital—which this chapter aims to accomplish.

Incorporating the Impact of Air Pollution into the Human Capital Calculations

This chapter estimates the impact of air pollution exposure on human capital by measuring the difference between human capital under actual pollution conditions and the hypothetical value of human capital if there were no premature deaths from air pollution. This approach captures just one aspect of the impacts of air pollution on human health—the most severe outcome, premature death. Although there are other channels through which air pollution exposure may have an impact on human capital, such as reduced productivity and labor force participation, this work focuses only on the impact of premature deaths using readily available data from the Global Burden of Disease Study.

As the human capital methodology suggested, survival rate is a critical parameter in the human capital calculations, since the probability of surviving one more year determines the population who will be in the workforce one more year. The survival rates used in the human capital calculations combine all causes of death, including premature mortality resulting from air pollution. To estimate the impact of air pollution in the human capital calculations, premature deaths resulting from air pollution are separated from the total number of deaths. Deaths are considered as air pollution–related if they are associated with any air pollution risk factors in the Global Burden of Disease Study data, including household air pollution from solid fuels, ambient particulate matter pollution, and ambient ozone pollution. Once the number of deaths caused by air pollution is excluded from the total number of deaths, the change in the death rates improves the survival rates. The survival rates are calculated as

$$v_{a+1}^{base} = 1 - death_a^{all\ \ causes}, \tag{8.1}$$

$$v_{a+1}^{air\ \ pollution} = 1 - death_a^{excl.\ air\ \ pollution}, \tag{8.2}$$

where $death_a$ is the death rate of age a, and v_{a+1} is the probability of surviving one more year of age a.

Therefore, the stock of human capital is calculated using the adjusted survival rates, as explained in chapter 7. The difference between the base human capital stock and the adjusted human capital stock is considered the hypothetical value of human capital if there were no premature deaths caused by air pollution.

$$\Delta HC = HC_{no\ \ air\ \ pollution} - HC_{with\ \ air\ \ pollution}. \tag{8.3}$$

It is important to note that mortality is valued within the framework of the human capital methodology, which uses a discounted lifetime income approach. The cost of premature deaths caused by air pollution represents the discounted value of the forgone labor income that sufferers of fatal illness would have earned over their remaining working lives had they not died. This income-based measure is different from a welfare-based approach to valuing mortality, and the welfare-based estimate can be magnitudes higher.

Estimates of the Impact of Air Pollution on Human Capital

At the global level, it is estimated that the cost of premature deaths caused by air pollution—including ambient particulate matter, household $PM_{2.5}$ from cooking with solid fuels, and ambient ozone—on per capita human capital was about US$290 in 2018 (table 8.1). In other words, globally

TABLE 8.1 Loss of Per Capita Human Capital Because of Premature Deaths Attributable to Air Pollution, by Income Group and Region, in US Dollar Terms, 1995–2018
2018 US$

Income group and region	1995	2000	2005	2010	2015	2018
Income group						
Low-income	51	46	45	20	54	58
Lower-middle-income	111	122	137	173	187	199
Upper-middle-income	215	243	289	332	399	413
High-income: non-OECD	927	866	786	772	741	675
High-income: OECD	649	614	513	417	362	342
Region						
East Asia and Pacific	236	273	327	384	470	489
Europe and Central Asia	328	288	259	261	212	198
Latin America and the Caribbean	210	190	167	146	166	167
Middle East and North Africa	238	224	216	236	230	213
North America	1,115	1,093	907	638	539	500
South Asia	100	120	132	162	187	208
Sub-Saharan Africa	84	78	82	103	110	105
World	**250**	**254**	**256**	**266**	**286**	**290**

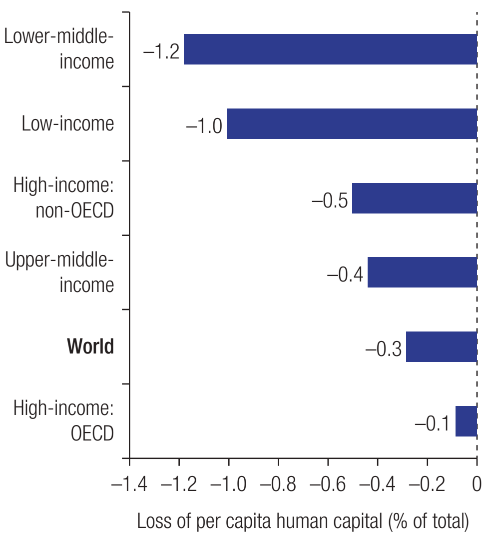
Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

per capita human capital would have increased by about 0.3 percent in 2018 if there were no premature deaths resulting from exposure to air pollution (figure 8.3 and figure 8.4). The estimates of the impact of eliminating air pollution suggest that there was a slight improvement in air quality at the global level from 1995 to 2018. The impact of the elimination of air pollution on human capital was 0.4 percent in 1995 and 0.3 percent in 2018 (table 8.2).

At the regional level, loss of human capital because of premature deaths from exposure to air pollution is quite variable, ranging from 0.1 percent in North America to 1.4 percent in South Asia in 2018. Since air pollution is quite high in South Asia, Sub-Saharan Africa, and the Middle East and North Africa, reducing air pollution will have a significant impact on human capital in the countries in these regions. Per capita human capital in South Asia could improve by US$208 if there were no premature deaths resulting from exposure to air pollution. Similarly, per capita human capital in Sub-Saharan Africa and the Middle East and North Africa is estimated to improve by US$105 and US$213, corresponding to increases of 0.9 and 0.7 percent, respectively. The loss of per capita human capital resulting from premature deaths from exposure to air pollution is estimated at only 0.1 percent in North America and Europe and Central Asia (table 8.1 and table 8.2).

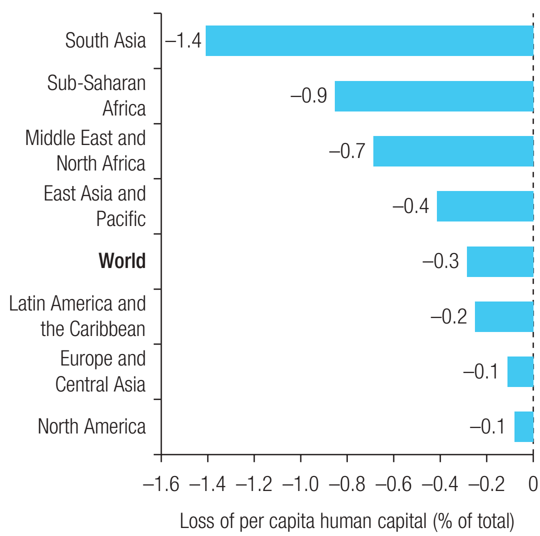
The estimates of the loss of per capita human capital because of premature deaths attributable to air pollution point out that the loss was greater than 1 percent in lower-middle-income and low-income countries, while the loss was only 0.1 percent in high-income Organisation for Economic Co-operation and Development (OECD) countries in

FIGURE 8.3 Loss of Per Capita Human Capital Because of Premature Deaths Attributable to Air Pollution, by Income Group, 2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

FIGURE 8.4 Loss of Per Capita Human Capital Because of Premature Deaths Attributable to Air Pollution, by Region, 2018



Source: World Bank staff calculations.

TABLE 8.2 Loss of Per Capita Human Capital Because of Premature Deaths Attributable to Air Pollution, by Income Group and Region, in Percentage Terms, 1995–2018
percent

Income group and region	1995	2000	2005	2010	2015	2018
Income group						
Low-income	1.4	1.3	1.2	0.5	1.1	1.0
Lower-middle-income	1.3	1.4	1.3	1.3	1.3	1.2
Upper-middle-income	0.7	0.7	0.6	0.5	0.5	0.4
High-income: non-OECD	0.7	0.7	0.7	0.6	0.5	0.5
High-income: OECD	0.2	0.2	0.1	0.1	0.1	0.1
Region						
East Asia and Pacific	0.5	0.5	0.5	0.5	0.4	0.4
Europe and Central Asia	0.3	0.2	0.2	0.2	0.1	0.1
Latin America and the Caribbean	0.5	0.4	0.3	0.3	0.3	0.2
Middle East and North Africa	0.9	0.8	0.8	0.8	0.7	0.7
North America	0.2	0.2	0.2	0.1	0.1	0.1
South Asia	1.6	1.7	1.6	1.6	1.5	1.4
Sub-Saharan Africa	1.1	1.1	1.1	1.0	0.9	0.9
World	**0.4**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**

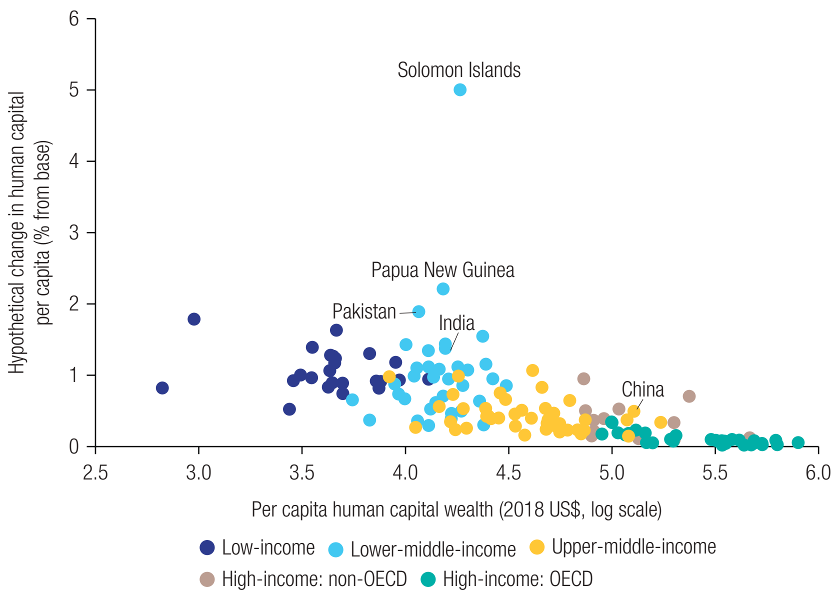
Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

2018 (table 8.1 and table 8.2). This indicates that the change in per capita human capital resulting from decreased air pollution becomes relatively smaller as total human capital increases because of economic growth. In addition, countries that suffer from air pollution are mostly lower-middle-income and low-income countries. The loss in per capita human capital in lower-middle-income countries and low-income countries is estimated at US$199 and US$58, respectively (table 8.1). In US dollar terms, the highest loss is US$675, which is estimated for high-income non-OECD countries because of some countries in the Middle East and North Africa.

At the country level, the loss of per capita human capital resulting from premature deaths attributable to air pollution is highest in the Solomon Islands, estimated at about 5.0 percent loss of per capita human capital in 2018. The loss of per capita human capital in Papua New Guinea and Pakistan was also quite high, at 2.2 and 1.9 percent, respectively (figure 8.5). These results are not surprising since the shares of air pollution–related premature deaths in the Solomon Islands, Papua New Guinea, and Pakistan are among the highest worldwide.

China and India need special focus in terms of reducing air pollution–related deaths. More than 1 million deaths are attributable to air pollution in each of these countries. In other words, about 12 percent of deaths in India and China are attributable to air pollution. As figure 8.5

FIGURE 8.5 Loss of Per Capita Human Capital Because of Premature Deaths Attributable to Air Pollution in relation to Development Level, 2018



Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

illustrates, about a 1.4 percent loss of per capita human capital is estimated in India and 0.5 percent in China because of premature deaths from exposure to air pollution in 2018. Although the numbers of deaths are close in these countries, the impacts of reducing air pollution–related deaths are quite different. The reason is that the magnitude of reducing or eliminating air pollution is smaller as income level increases. As illustrated in figure 8.5, the magnitude of the loss of per capita human capital because of premature deaths stemming from exposure to air pollution is higher in low-income and lower-middle-income countries.

Conclusion

Air pollution is one of the world's leading health risk factors after high systolic blood pressure and smoking. In addition to premature deaths, air pollution has diverse adverse effects, including but not limited to worsening cognitive performance, reducing labor productivity, damaging children's health, and reducing students' ability to benefit from education. Additionally, there are airborne pollutants other than $PM_{2.5}$ that are harmful to health (box 8.3).

Although air pollution has some significant productivity effects on human capital, it is difficult to measure the precise effects of air pollution

BOX 8.3 More Research Is Needed on the Health Impacts of Air Pollution

Air pollution is associated with many detrimental but less researched health impacts and conditions (Sánchez-Triana et al. 2015; World Bank 2020; World Bank 2021b), such as infant mortality (Heft-Neal et al. 2018), low birth weight (Ezziane 2013), preterm delivery (Liu et al. 2019), mental health problems (Shin, Park, and Choi 2018), neurological impairment (Xu, Ha, and Basnet 2016; Zhang, Chen, and Zhang 2018) including dementia in later life (Carey et al. 2018), type 2 diabetes (Bowe et al. 2018), and irreversible eyesight loss (Chua et al. 2021). Dose-response functions have been established for $PM_{2.5}$ and the following health outcomes: (1) ischemic heart disease, (2) lung cancer, (3) chronic obstructive pulmonary disease, (4) strokes, and (5) acute respiratory infections in children. However, further research is needed to establish exposure-response functions, which will enable the estimation of the health burden of air pollution associated with additional health conditions.

In addition to $PM_{2.5}$, other airborne pollutants are harmful to health, including, among others, ozone, lead, mercury, and pesticides. For example, lead is particularly toxic to children even in small amounts and can compromise their ability to grow up to become productive members of their societies. Lead poisoning in children causes damage to the brain and nervous system, slowed growth and development, and learning and behavior problems. Furthermore, there is no known safe level of lead exposure in children. More research is needed to better understand the relationships between exposure to these pollutants and specific health outcomes. In addition, there is a need for air quality monitoring efforts in developing countries that include measurements for these pollutants. The shortcomings in air quality monitoring in developing countries pose additional challenges. Furthermore, there is a need to understand, through source apportionment analyses in specified locations (regions and countries), the contributions of these pollutants to the air quality that people in those locations are exposed to.

on labor productivity and cognitive performance. Therefore, this chapter has provided the impact of air pollution exposure as the gap between human capital estimated under actual pollution conditions and the hypothetical value of human capital if there were no premature deaths from exposure to air pollution in 146 countries throughout 1995–2018.

The estimates suggest that the loss of per capita human capital globally because of premature deaths attributable to air pollution was about 0.3 percent in 2018. On average, the percentage loss of per capita human capital is greater for lower-middle-income countries, highlighting the importance of improving air quality management in developing countries where one of the many benefits would include higher human capital.

In addition, COVID-19 has exacerbated the premature deaths from exposure to air pollution. A significant fraction of worldwide COVID-19 mortality is attributable to the long-term exposure to ambient fine particulate air pollution (Cole, Ozgen, and Strobl 2020; Pozzer et al. 2020). In addition, some recent research shows that higher historical $PM_{2.5}$ exposures are positively associated with higher country-level COVID-19 mortality rates (Wu et al. 2020). Furthermore, people with underlying health conditions, such as respiratory illness caused by exposure to air pollution, might have a higher risk of death following COVID-19 infection (Yamada, Yamada, and Mani 2021). Because of data limitations, this chapter has not provided estimates of the loss of human capital because of COVID-19 mortality, but if detailed data become available, this analysis can be incorporated into future work.

Future work could also explore the potential productivity gains from reducing air pollution and its impact on human capital. Future editions of *The Changing Wealth of Nations* could also provide a more detailed breakdown of the impact of air pollution on human capital, disaggregated by indoor and outdoor air pollution. In addition, information on the duration of exposure to air pollution before death occurs could improve this analysis. Deaths caused by air pollution can take place in different time periods depending on the form and impact of the air pollution.

Note

1. DALY is a composite metric that combines the years of life lost because of premature death and the years lived with disability.

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PART III

Applying Wealth Accounts for Policy Analysis

9

The Nonrenewable Wealth of Nations

James Cust and Alexis Rivera Ballesteros

Main Messages

- Nonrenewable assets make up a significant share of total wealth in many countries: for example, 31 countries have more than 5 percent of their total wealth in nonrenewable natural capital.
- Despite being a depleting asset, the nonrenewable wealth of nations more than doubled between 1995 and 2018, from US$13 trillion to US$30 trillion.
- Overreliance on nonrenewable natural capital has proven risky. Price drops since 2014 have seen nonrenewable wealth decline by 35 percent in just four years—down from US$46 trillion to US$30 trillion by 2018. Nonrenewable natural resource–rich countries have failed to diversify their exports. A focus on diversification of their asset base may help promote resilience and sustain economic growth.
- Nonrenewable wealth forms an inverted-U shape, similar to the Environmental Kuznets curve. This means it often forms a low but rising share of wealth at lower income levels, and a higher but declining share for countries with higher levels of national income.
- The low-carbon transition may significantly alter the demand for and prices of fossil fuels, posing additional risks. Countries abundant in metals and minerals that are important for low-carbon technologies, such as batteries and wind turbines, may see growing demand.

Introduction

Nonrenewable resources, comprising oil, natural gas, coal, metals, and minerals, make up only 2.5 percent of total wealth in the world, equivalent to about US$30 trillion in 2018 or 36 percent of global gross domestic product (GDP). However, these assets are distributed unevenly and can constitute a major share of total wealth in some countries. For example, there are 31 countries where nonrenewable natural capital exceeds 5 percent of total wealth. As a consequence, they form an important source of export income and government revenue for many countries.

In fossil fuel–rich countries, the share of nonrenewable natural capital can reach more than 90 percent of the nation's total natural capital or more than one-third of its total wealth. These countries can be found all across the world, from Saudi Arabia in the Middle East and North Africa region (MENA) to Equatorial Guinea in Sub-Saharan Africa, Azerbaijan in Central Asia, and to Trinidad and Tobago in Latin America and the Caribbean. In addition, some countries have a high share of nonrenewable natural capital derived from metals and minerals, rather than carbon dioxide–emitting fossil fuels. For example, more than 50 percent of Chile's and almost 25 percent of Guinea's natural wealth was held in mineral resources in 2018, representing 6 and 15 percent of these countries' total wealth, respectively. Latin America and the Caribbean and Sub-Saharan Africa are the regions with relatively higher shares of mineral wealth compared to their fossil fuel wealth.

The extraction of nonrenewable natural capital generates an economic rent that can make it a major source of government income and a big part of the economy. The annualized flow of nonrenewable resource rents between 1995 and 2018 reached more than 50 percent of GDP in many oil-rich countries, including Equatorial Guinea, Iraq, Kuwait, Libya, and the Republic of Congo. In other countries, such as Mongolia and Suriname, the combination of the rents obtained from the extraction of fossil fuels and metals and minerals reached one-third of the total value of their economy in the same period.

Traditional Risks from Natural Resource Abundance

The high share of government revenues formed by nonrenewable resources and the associated economic dependence on them can present many challenges to these countries. Previous studies have discussed these challenges and warned of their risks, most famously referred to as the *resource curse* (van der Ploeg 2011). The resource curse hypothesis posits that abundance of nonrenewable resources can lead to worse economic outcomes than might occur in their absence. One example of how the resource curse can manifest is via a distortion of the real exchange rate, driven by resource booms, known as the Dutch disease (Barma et al. 2012; Corden and Neary 1982). This in turn can undermine competitiveness of the economy and shrink, or hold back, traded sectors such as manufacturing and commercial agriculture.

The record of economic performance among resource-rich countries is mixed. Natural resources can raise the income of a country, and successful countries have used the proceeds from resource extraction to invest in other forms of capital, including diversification of economic activity and enhancement of human capital via health and education investments (Bravo-Ortega and De Gregorio 2005; Stijns 2006). However, natural resource booms can shift labor from non-resource-intensive to resource-intensive sectors, favoring lower-skill jobs, increasing the opportunity cost of education, and otherwise impeding the growth of other sectors that rely more on highly-skilled human capital. These channels may lead to a reduction or a delay in human capital accumulation, particularly in lower-income resource-rich countries, where there is generally scarce human and physical capital (van der Ploeg and Venables 2011).

Human capital is not the only form of wealth that can suffer. The economic rents generated by natural resource extraction can also induce other rent-seeking behavior that can lead to unequal fiscal distribution, inefficient and unproductive revenues, poor governance, and corruption (Arezki and Gylfason 2013; Robinson and Torvik 2005). This can undermine the overall level of capital accumulation in the economy, limiting the extent to which countries offset the loss of wealth from resource extraction with increases in other capital stocks. Chapter 11 explores the process of wealth diversification, which resource-rich countries have found particularly difficult to navigate. Chapter 12 examines the impact of natural resource abundance on human capital accumulation.

New Risks from Natural Resource Abundance

Beyond the resource curse, the twenty-first century brings a new set of challenges that may exacerbate economic challenges associated with natural resource abundance. For example, van der Ploeg and Rezai (2020) discuss the risk facing fossil fuel–rich countries of assets being stranded at the end of the fossil era and unanticipated changes to the timing and intensity of global climate policy. Manley, Cust, and Cecchinato (2016) suggest that effective global climate policies might lead to “stranded nations,” referring to economies with significant fossil fuel reserves.[1] As global energy consumption shifts away from fossil fuels, the economic viability of extracting these resources may decline, and incentive for additional exploration may also fall. Since subsoil resources are almost universally owned by countries rather than companies, it is likely that countries will bear the brunt of this risk. The BP Energy Outlook (2020) predicts a decline in the demand for fossil fuels over the next 30 years, suggesting that a net zero scenario would lead to a halving of 2020’s level of fossil fuel demand, while renewable sources of energy will fill that gap.

How the world navigates the low-carbon transition could determine how the value of nonrenewable natural capital evolves into the future and, in turn, how the overall wealth of resource-rich countries is affected (Peszko et al. 2020). This issue, and the potential policy pathways to manage this risk, is explored in more detail in chapter 10.

It is not just fossil fuels that would be affected by a global carbon transition. Helm (2017) suggests that renewable energy sources will benefit from sustained technical progress and climate policy, eventually ending the fossil fuel age. Such a transition could drive additional demand for metals and minerals, as highlighted in recent World Bank studies (Peszko et al. 2020; World Bank 2017). This may present an economic opportunity to expand production of these metals and minerals in resource-abundant countries. However, capitalizing on this opportunity will depend on how rapidly countries can adjust supply to meet this rising demand (Galeazzi, Steinbuks, and Cust 2020).

This chapter presents the distribution of fossil fuel and mineral nonrenewable natural capital in different countries and across regions of the world. It explores how these wealth estimates are constructed and the uncertainties associated with valuing nonrenewable assets. Finally, the chapter discusses the risks and challenges faced by countries with high dependence on nonrenewable resources and the drivers of change in nonrenewable wealth over the past two decades.

Global Distribution of Fossil Fuel and Mineral Wealth

Fossil fuel and mineral assets are unequally distributed around the world. Some regions, like MENA, have vast stores of nonrenewable wealth, exceeding 35 percent of total wealth in the region. This wealth is almost entirely based in fossil fuels. In other regions, such as Latin America and the Caribbean, nonrenewable resource wealth is spread roughly equally between fossil fuel wealth and mineral wealth. The latter includes metals such as copper and iron ore. Similarly, while low-income countries and those of the Organisation for Economic Co-operation and Development (OECD) have the lowest shares of nonrenewable wealth in total wealth, the group of non-OECD high-income countries' nonrenewable wealth reached 30 percent of the income group's total wealth in 2018. This reflects the special characteristics of these countries, many of which are classified as high-income largely as a consequence of the scale of natural resource revenues generated in their economy.

Given the wide variation in nonrenewable natural capital combinations, each region faces different challenges and opportunities posed by the low-carbon energy transition. Table 9.1 shows the distribution of wealth in different regions and income groups.

Fossil fuel wealth is more abundant than mineral wealth in the world; most of it is concentrated in MENA and upper-middle-income countries. According to the latest Changing Wealth of Nations (CWON) data, MENA is the region with the largest amount of global fossil fuel wealth (see figure 9.1, panel a), holding 52 percent of the world's total. This primarily comprises petroleum resources. This massive amount of fossil fuel wealth located in countries around the Persian Gulf is more than three times the amount found in any other region.

By income groups, the countries with the largest share of fossil fuel wealth are those classified as upper-middle-income, as figure 9.1, panel b, shows. Not only do they hold almost half of the world's fossil fuel wealth (46 percent), but they also hold the largest share of metals and minerals wealth (45 percent). This group of countries includes large economies, led

TABLE 9.1 Distribution of Wealth, Including Nonrenewable Wealth, by Region and Income Group, 2018
% of total wealth

Region and income group	Natural capital	Produced capital)	Human capital	Nonrenewable natural capital
Region				
East Asia and Pacific	4.1	27.6	67.0	1.2
Europe and Central Asia	3.9	40.1	55.8	1.7
Latin America and the Caribbean	10.9	29.3	62.2	3.2
Middle East and North Africa	37.6	25.0	30.1	35.1
North America	2.2	30.1	70.6	0.6
South Asia	11.9	25.5	65.1	2.2
Sub-Saharan Africa	19.5	22.6	60.0	5.3
Income group				
Low-income	25.6	27.7	50.0	2.4
Lower-middle income	13.5	27.2	62.1	3.3
Upper-middle income	7.9	25.8	66.2	3.6
High-income: non-OECD	30.8	23.2	33.6	29.9
High-income: OECD	2.1	35.0	63.8	0.6
World	**5.6**	**31.2**	**63.6**	**2.5**

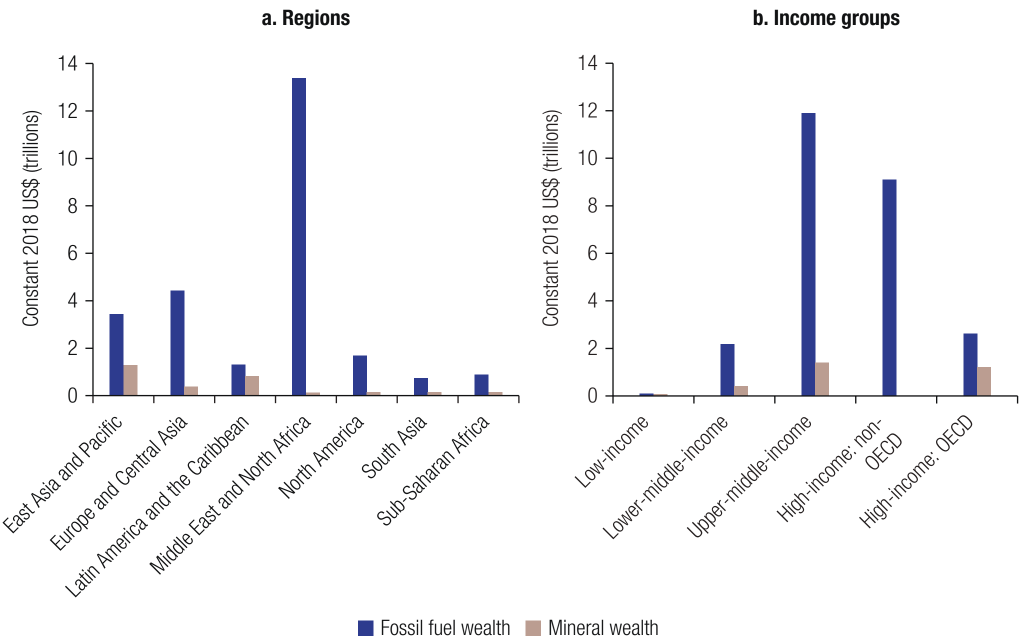
Source: World Bank staff calculations.
Note: The first three columns may not sum to 100 because the category of net foreign assets is not shown. OECD = Organisation for Economic Co-operation and Development.

by the Russian Federation, China, and the Islamic Republic of Iran, and another 36 countries with nonrenewable natural capital that exceeds US$1 billion.

When a country derives a large share of its GDP, export receipts, or government revenues from natural resource wealth, it is often referred to as *resource rich* or *resource dependent* (IMF 2012b). This classification can similarly be extended to countries with large shares of wealth concentrated in these assets. By this metric, the largest number of resource-dependent countries in terms of fossil fuels are found in the MENA region. Meanwhile, the economies with the highest dependence on mineral wealth are located Latin America and Sub-Saharan Africa. One of these Sub-Saharan African countries, Guinea, is the only country in the world where metal and mineral assets exceed 15 percent of the country's total wealth.

Resource dependence based on wealth is closely related to measures of resource dependence based on revenues, such as share of total government revenues. This is because subsoil resources are typically owned by governments and are taxed or sold with a significant share of the proceeds going to government. Governments as resource owners have the objective to capture the economic rents arising from resource extraction and sale.

FIGURE 9.1 Distribution of Fossil Fuel and Mineral Wealth, by Region and Income Group, 2018

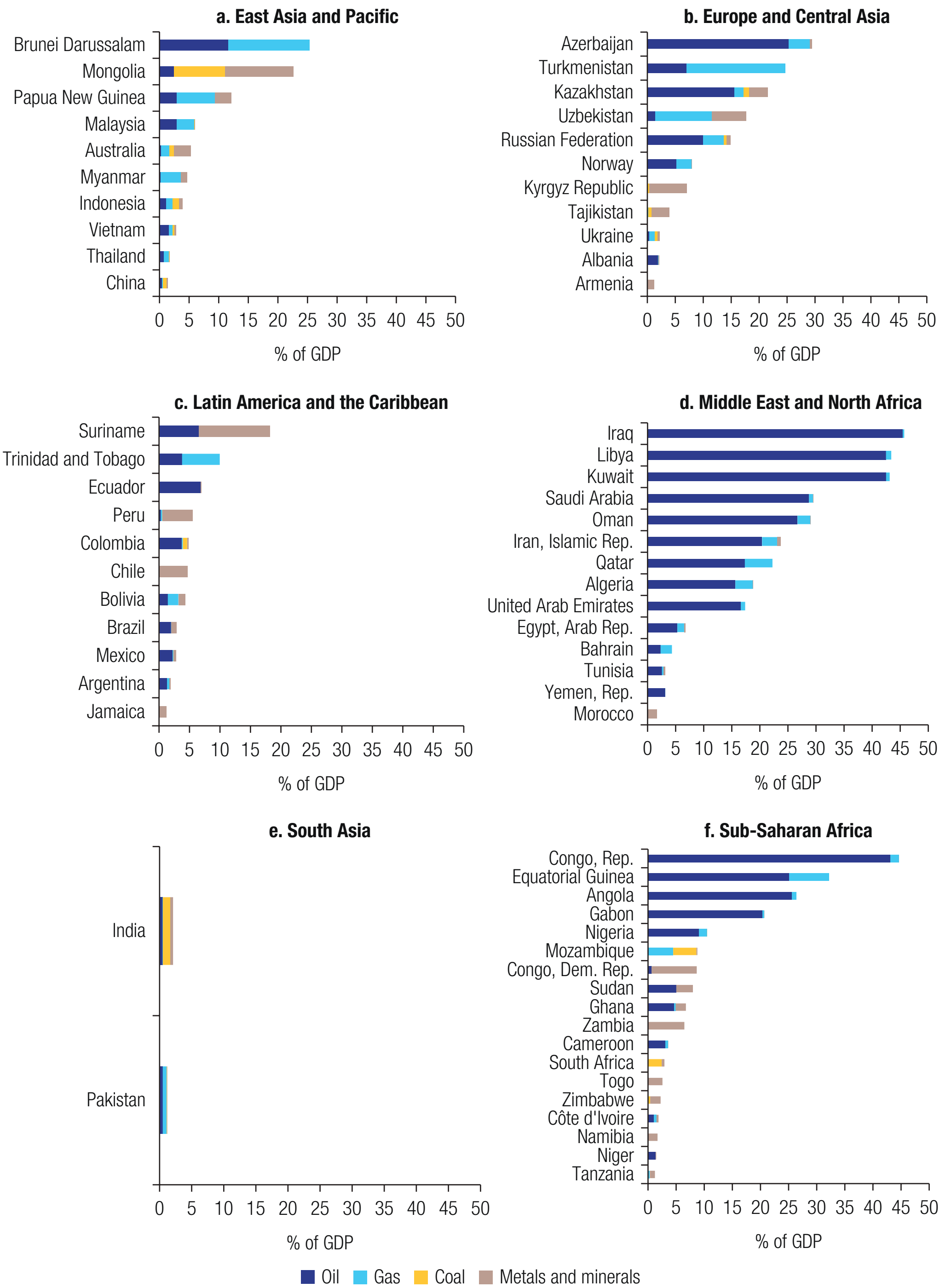


Source: World Bank staff calculations.
Note: OECD = Organisation for Economic Co-operation and Development.

Nonrenewable natural resource rents are the difference between the cost of production and the estimated revenue from the sale of fossil fuels or minerals (annex 9A details how these rents are calculated). In 67 countries, the rents from nonrenewable natural capital exceed 1 percent of the nation's GDP (see figure 9.2). Among these, there are 16 countries in East Asia and Pacific, Europe and Central Asia, MENA, and Sub-Saharan Africa where rents obtained from nonrenewable natural capital exceed 20 percent of the countries' GDP. In all these countries, the largest source of rents comes from fossil fuel assets. For example, in the Republic of Congo, fossil fuel rents reached 43 percent of the country's GDP in 2018. It is important to note that rent numbers reported by CWON are estimates. Because, among other things, the costs of production are not readily observable and vary over the lifetime of an extraction project, there can be significant uncertainty contained within these estimates. Further, while governments seek to tax the rents generated from extraction, it has proven very challenging to capture the full rental value as revenues for government. Box 9.1 discusses these issues in more detail.

Since 1995, the world's fossil fuel wealth has more than doubled. This has been accompanied by increasing fossil fuel wealth in most countries in the world (95 in total). Between 1995 and 2018, the world's fossil fuel wealth increased from US$12 trillion to US$26 trillion, an increase of

FIGURE 9.2 Nonrenewable Natural Capital Rents' Share of GDP, by Region and Country, 2018



Source: World Bank staff calculations.
Note: The figure displays only those countries with nonrenewable natural capital rents greater than 1 percent of GDP. North America is not shown because only Canada has nonrenewable natural capital rents greater than 1 percent of GDP (1.8 percent from oil, 0.1 percent from gas, 0.8 percent from coal, and 0.1 percent from minerals). GDP = gross domestic product.

BOX 9.1 Rent and Government Revenues: Why Are They Not the Same?

Nonrenewable wealth estimates depend on calculation of rents, since rents form the discounted stream of benefits that are used to value the asset in wealth accounting. However, calculating rents is challenging. And even if they could be measured perfectly, it is an even more difficult task for governments to capture them via taxation. For that reason, government revenues rarely get close to the full annual rent value of resource extraction. Therefore, interpretation of rent numbers—for example, to inform policy making—should consider these complications.

Rent calculations estimate the difference between the cost of extraction and the typical price of sale. Conceptually, this can be thought of as equivalent to the compensation the resource owner—typically a country—should receive for resource extraction. Meanwhile, the company is entitled to recoup its costs plus a reasonable return on its capital investment. However, estimates of rents provided in the Changing Wealth of Nations (CWON) do not distinguish between what the government gets and what the company receives. As such, rent numbers should be considered closer to an upper bound of what might accrue to the country that owns the resource.

There are two reasons why rents do not equal government revenues. First, it is a widely held view (see, for example, Daniel, Keen, and McPherson [2010]) that governments fail to capture the maximum available rents associated with nonrenewable resource extraction. The reasons for this may include differential risks being borne, significant uncertainties across time, asymmetries of information, and the difficulties tax administrators experience in measuring companies' tax bases (Cust and Manley 2018). Using data from Rystad Energy UCube, which is the source for this CWON's petroleum unit rent numbers, it is calculated that between 2010 and 2014, governments took, on average, 77 percent of the total rents available. This is similar to the 65 to 85 percent discounted average effective tax rates considered "reasonably achievable" by the International Monetary Fund (IMF 2012a).

The second reason is that the risk-adjusted cost of capital for fossil fuel industries may be higher than captured by the rent estimates. If the risk-adjusted cost of capital is high in a particular country, the rent available for the country to tax may be lower than estimated in the CWON data set. This might be because of hidden costs, including political risks, that raise the risk premium for investors to operate in a particular jurisdiction. Investors may be deterred from, and therefore require greater compensation for, investing in countries with, for example, weak governance (Cust and Harding 2020). This could help explain why governments are unable to recover the full amount of potential rent.

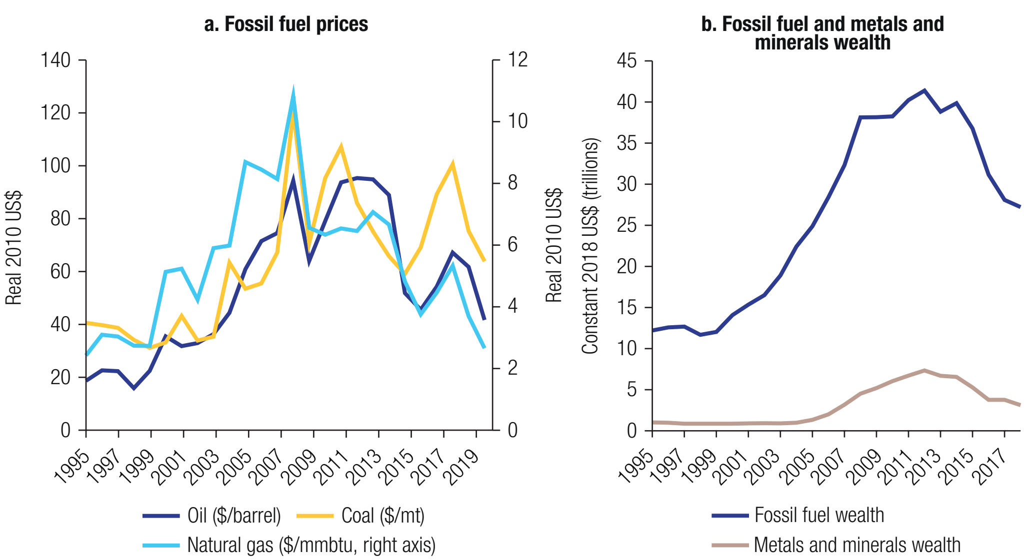
Governments should therefore interpret the rent numbers cautiously. Higher rent estimates may signal that additional tax revenues could be captured. The means for capturing them, however, may involve reducing political and other risks, reducing costs of doing business, as well as negotiating better deals or taxing more effectively. Managing low-carbon transition risk may increase pressure for governments to try to squeeze more revenues from existing projects, especially if petroleum prices start declining. Therefore, policies that reduce investor risks may help increase the rents available to be taxed.

Furthermore, efforts to support better rent capture by governments, such as providing technical assistance to governments engaged in contract negotiations or assistance in auctioning fossil fuel extraction rights, might be helpful in the global effort to mitigate carbon emissions. The reason is that any undertaxation of extraction by the government functions as a form of implicit production subsidy. This subsidy might therefore induce overextraction relative to a situation where producers face the full social cost of carbon (that is, a carbon tax or price) and the full private cost of extraction (that is, including full rent taxation). If the low-carbon transition places downward pressure on fossil fuel prices, governments might even be tempted to lower taxes to maintain production levels. However, if this comes at the expense of rent capture, it may also shortchange citizens as the ultimate beneficiaries of subsoil wealth.

approximately 117 percent. Rising oil prices and new petroleum discoveries contributed to this growth. The prices of oil, natural gas, and coal started to rise rapidly during the first years of the 2000s, peaked between 2008 and 2013, and started to drop after 2014 (figure 9.3, panel a). For example, the average price of oil was US$18.69 (real 2010 US dollars) per barrel in 1995 and reached its maximum in 2012, an average of US$95.31, a rise of 400 percent. At this peak, the world's fossil fuel wealth was already three times higher than the global value of fossil fuel wealth in 1995 (figure 9.3, panel b). But the effect of oil prices falling in 2014 led to a reduction in fossil fuel wealth, from US$41 trillion to US$27 trillion by 2018. However, despite this decline, fossil fuel wealth is still at least five times larger than metals and minerals wealth.

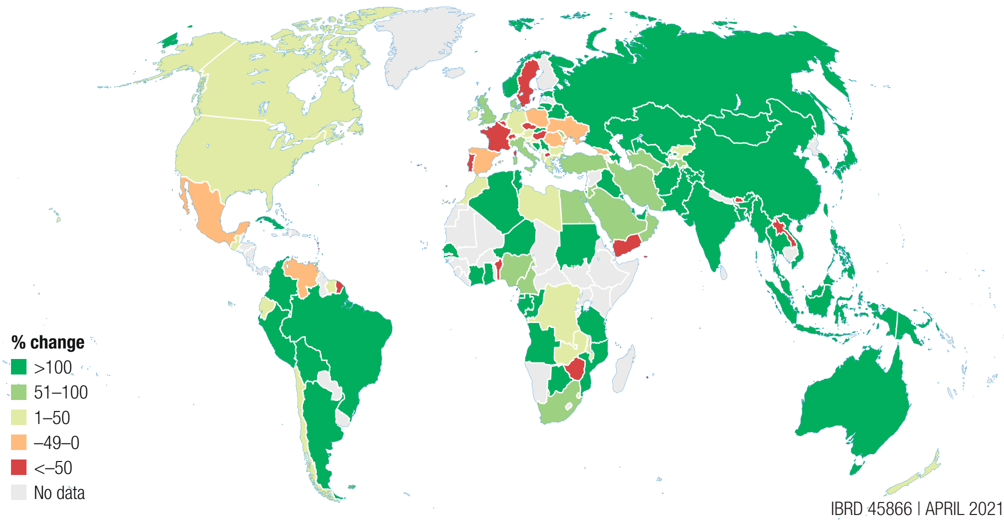
Fossil fuel wealth has not expanded or shrunk at the same rate in all countries. Different depletion speeds and the discovery of new reserves have affected the magnitude of fossil fuel wealth in each. Since 1995, more than 240 giant petroleum and natural gas fields have been discovered, with 14 of them holding more than 5 billion barrels of oil equivalent (Cust, Mihalyi, and Rivera-Ballesteros, forthcoming). For example, Brazil found at least 22 fields holding more than 500 million barrels of oil equivalent between 1995 and 2018, which, alongside rising production volumes, has contributed to almost tripling the country's fossil fuel wealth. By contrast, 20 countries and regions saw significant declines in their fossil fuel wealth between these years, mainly driven by increasing depletion,

FIGURE 9.3 Fossil Fuel Prices, and Fossil Fuel and Metals and Minerals Wealth



Source: World Bank staff calculations.
Note: Fossil fuel wealth includes crude oil, natural gas, and coal. Metals and minerals wealth includes bauxite, copper, gold, iron ore, lead, nickel, phosphate, silver, tin, and zinc. mmbtu = million British thermal units; mt = metric tons.

MAP 9.1 Change in Fossil Fuel Wealth, 1995–2018

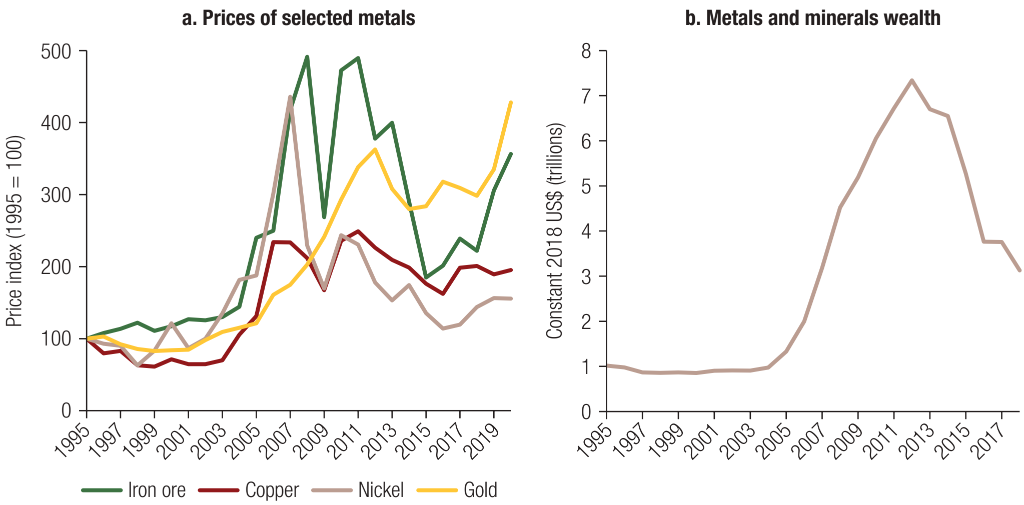


Source: World Bank staff calculations.
Note: Fossil fuel wealth includes oil, gas, and coal.

falling production volumes, and limited numbers of new discoveries (see map 9.1). For example, according to World Bank staff estimates, fossil fuel depletion in Mexico increased five times, from US$5 billion in 1995 to US$25 billion in 2018, while the country discovered fewer than five fields the size of those found in Brazil. This has contributed to a decline in Mexico's fossil fuel wealth, which fell from US$400 billion in 1995 to US$227 billion in 2018, a decline of 43 percent in 23 years.

Since 1995, total global mineral wealth has more than tripled as a consequence of the increasing mineral wealth in 77 countries and regions. The world's mineral wealth grew from US$1.0 trillion to US$3.1 trillion between 1995 and 2018. In 77 of 121 countries and regions with positive mineral wealth, the value of minerals and metals has increased, and for 65 of them, mineral wealth has more than doubled. The increase in the prices of several metals and minerals during the 2004–14 commodity boom and new reserves through the discovery of new deposits brought a fast increase of mineral wealth, particularly after 2008. Between 1995 and 2018, the real prices of all metals and minerals covered by this wealth measure increased (figure 9.4, panel a). The price of gold had the largest increase, tripling over this period. It rose from an average of US$418 per troy ounce in 1995 to US$1,247 per troy ounce in 2018, and it has continued to increase, especially when the COVID-19 pandemic started. The increase in the price of gold is followed by increases in the prices of silver, iron ore, lead, tin, and nickel. The latter more than tripled over 2004–14 but slightly declined after 2014. The price of nickel went from US$8,951 per metric ton (mt) in 1995 to US$39,013 per mt in 2007 and declined to

FIGURE 9.4 Indexed Prices of Selected Metals, and Metals and Minerals Wealth, 1995–2018

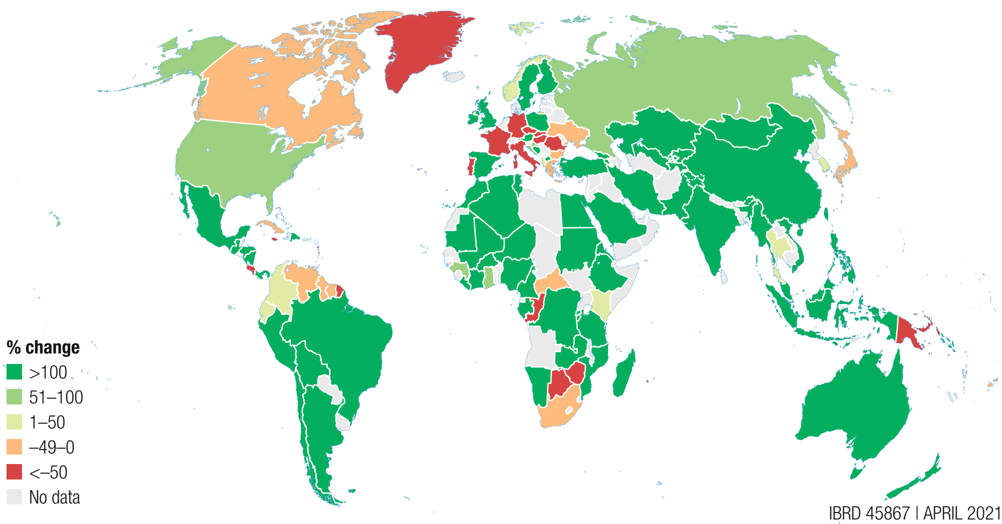


Source: World Bank staff calculations using World Bank commodity price data.
Note: Metals and minerals wealth includes bauxite, copper, gold, iron ore, lead, nickel, phosphate, silver, tin, and zinc.

US$13,928 per mt in 2018, still almost twice the price in 1995. These jumps in prices contributed to the increase of metals and minerals wealth from US$1.3 trillion in 2005 to US$7.3 trillion in 2012, a fivefold increase over about seven years (figure 9.4, panel b).

Newly discovered metal and mineral deposits have contributed to the increase in countries' mineral wealth. New metal and mineral deposits have been found all over the world, contributing to a rapid increase in the use of metals and minerals in production. According to the United States Geological Survey *Mineral Yearbook* (USGS 2020), global gold mine production went from 2,200 mt of gold content in 1995 to 3,260 mt in 2018. In some countries, these new discoveries have significantly increased mineral wealth. According to the same *Mineral Yearbook* data, Burkina Faso reached gold production of 46,000 kilograms of gold content in 2017; it was only about 1,000 kilograms in the late 1990s. Thus, mineral wealth in Burkina Faso rose from US$125 million in 1995 to US$4.8 billion in 2018, an increase of about 3,700 percent. However, in almost one-fourth of the 105 countries and regions with mineral wealth data, the value of their mineral assets decreased between 1995 and 2018 (see map 9.2). Countries that saw falling mineral wealth include mineral-rich countries, like Papua New Guinea and South Africa, where mineral wealth dramatically dropped after the end of the commodity boom, in large part because of the price effect. Mineral wealth in Papua New Guinea went from US$15 billion in 1995 to US$30 billion in 2010 but quickly dropped to US$7 billion in 2018. Similarly, mineral wealth in South Africa went from US$60 billion in 1995 to US$100 billion in 2010 but dropped to

MAP 9.2 Change in Metals and Minerals Wealth, 1995–2018



Source: World Bank staff calculations.
Note: Metals and minerals wealth includes bauxite, copper, gold, iron ore, lead, nickel, phosphate, silver, tin, and zinc.

US$45 billion in 2018, driven in part by a decline in the country's gold production.

Annex 9A describes the conceptual approach to valuing nonrenewable natural capital. However, there are significant uncertainties about the future value of nonrenewable natural capital. For example, since 2018, the final year of the CWON 2021 wealth accounts, the price of oil and other commodity prices have experienced major fluctuations for several reasons: for example, as a consequence of the COVID-19 pandemic in 2020. Wealth measures depend on making assumptions about the future path of rents, which in turn are a function of many factors, including future production and prices. The CWON methodology adopts a standard approach of applying a five-year average price and extrapolating it forward.[2] However, no one knows how prices will evolve, and therefore estimates of current wealth—since they depend on the estimated net present value of future rents—are not certain. Additional uncertainty comes from expectations about the global carbon transition. Chapter 10 explores the implications if future fossil fuel prices are affected by this transition and associated policy responses, and it examines the implications for wealth.

Challenges for Nations Rich in Nonrenewable Resource Wealth

Countries with a high share of fossil fuel–based natural capital face four interlinked policy challenges related to the carbon intensity of their wealth: (1) high exposure to low-carbon transition risks, which could reduce the value of subsoil wealth; (2) high potential for reduced government revenues derived from fossil fuel wealth; (3) policies and investments that might further increase low-carbon transition risk; and (4) the difficulty of diversifying away from nonrenewable natural capital (Cust and Manley 2018).

Future market prices of fossil fuels are uncertain, but they may be lower as the world transitions to low-carbon energy sources. The value of nonrenewable natural capital in the CWON core accounts does not take account future changes in prices or policies as part of the global low-carbon energy transition and the changing climate. Therefore, the net present values are unlikely to yield correct predictions of the path of rents in the future. For example, a decline in demand for fossil fuels due to climate policies and the falling costs of alternative energy technologies might permanently lower the value of a country's fossil fuel wealth if demand and prices fall in the future. In other words, countries that are rich in fossil fuel wealth may face significant but uncertain downside risks in the future. These risks, and how policy might respond, are discussed in detail and simulated quantitatively in chapter 10.

Market prices for some metals and minerals may rise as part of the low-carbon transition. And rising demand for transition minerals could drive higher prices in the future (Galeazzi, Steinbuks, and Cust 2020)—for example, prices for those metals and minerals that may be needed for low-carbon energy technologies, such as lithium or cobalt for batteries. This would imply that the current mineral wealth estimates understate how valuable these assets may be going forward. In other words, countries that are rich in transition minerals may face upside risks in the future from changes in technology deployments and new global trends (Hund et al. 2020).

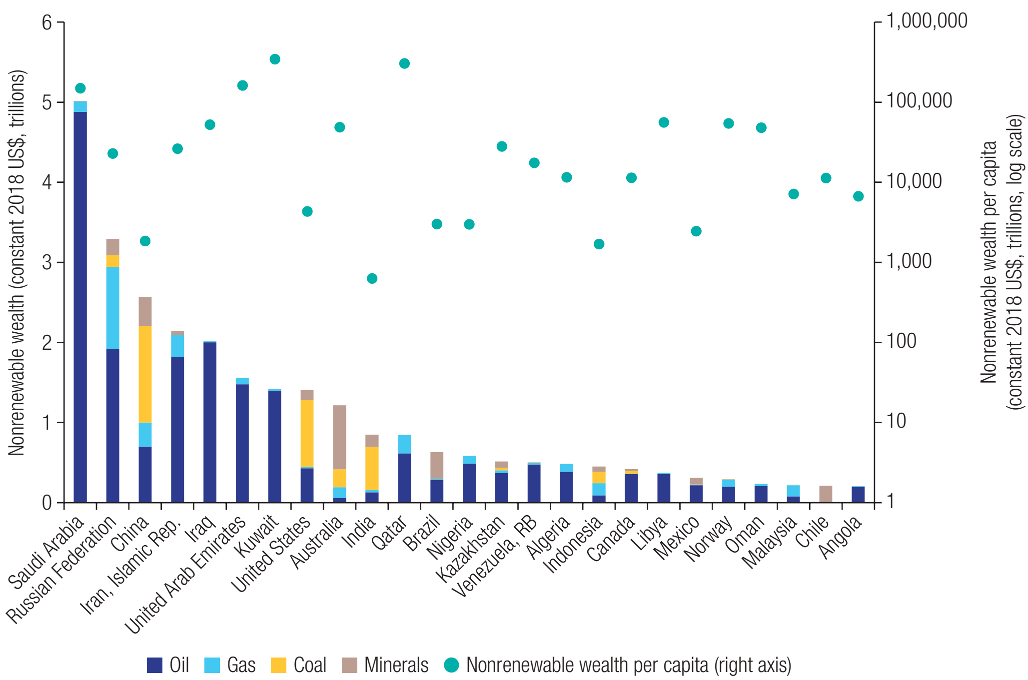
Fossil fuel–rich countries and mineral-rich countries may face divergent futures. This might also imply a policy bifurcation—whereby carbon-rich countries may need to mitigate downside risks, for example by accelerating diversification away from fossil fuel dependence and exposure to low-carbon transition risk. Meanwhile, countries that are rich in transition minerals may seek to position themselves to benefit from the upside risks—such as by increasing production of key minerals or developing more downstream value addition in key strategic sectors. The future of countries that are rich in nonrenewable natural capital will depend on how they manage to diversify their asset portfolio: for example, by investing in human capital or building their stock of productive assets and enhancing the value of renewable natural capital. Diversification in assets offers an alternative to traditional diversification recommendations, which often focus on export diversification—which can be difficult in the face of the Dutch disease induced by nonrenewable exports (Harding and Venables 2016; Ross 2019)—or downstream value addition—which in the case of fossil fuels might lead to increasing carbon intensity of the economy and, therefore, additional carbon risk (Peszko et al. 2020).

A diversification approach that focuses on enhancing the stock of other assets—human capital, productive capital, and renewable natural capital—may help mitigate these risks. Indeed, this may prove to be a more expedient pathway for economic diversification and sustainable prosperity, not least since it does not face the same competitiveness obstacles as export diversification. Asset portfolio diversification is further discussed in chapter 11 and in Peszko et al. (2020).

Exposure to Low-Carbon Transition Risks

The countries with the largest amounts of nonrenewable natural capital are also the countries with the highest exposure to low-carbon transition risks. Indeed, 18 of the 25 countries with the largest amounts of nonrenewable natural capital in the world are not well prepared for a low-carbon transition, according to Peszko et al. (2020). In these 18 countries, fossil fuel wealth exceeds more than US$0.1 trillion and can reach more than US$100,000 per person (figure 9.5). The countries that currently enjoy rents from these vast resources might not continue doing so in the future. With recent efforts to decarbonize the global economy, the demand for oil, gas, and coal could pull down the prices of these commodities, negatively impacting the rents from their extraction. More diversified economies with large amounts of nonrenewable natural capital, like Australia and the United States, might face a lower impact, since they are less exposed to low-carbon transition risks.

FIGURE 9.5 Nonrenewable Natural Capital of the Top 25 Countries, 2018

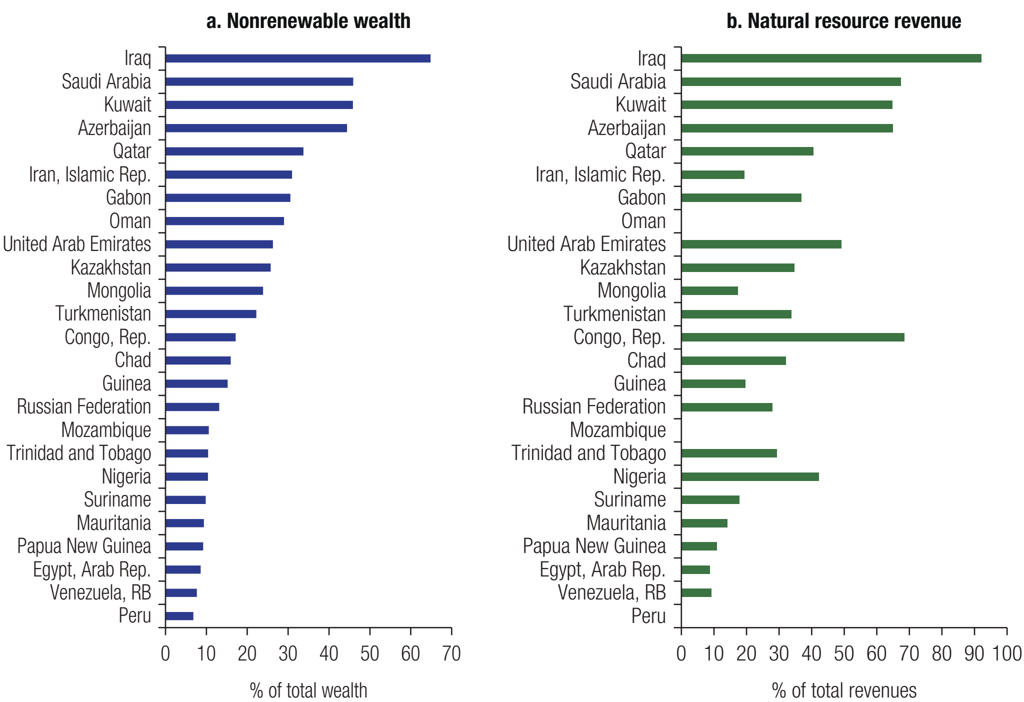


Source: World Bank staff calculations.

Other countries have managed to transition from a high share of fossil fuel wealth to a higher share of mineral wealth. For example, after the 2008 financial crisis, mineral wealth became the most important type of nonrenewable natural capital in Brazil, where oil wealth was between 60 and 70 percent of its total nonrenewable natural capital in previous years. In 2018, Brazil's oil wealth share of total nonrenewable wealth dropped to less than half, and minerals reached 53 percent of nonrenewable wealth. The income generated by this wealth dwarfs that which currently is derived from Brazil's rich and biodiverse renewable natural capital.

The high rents from nonrenewable natural capital generate outsized government revenues in countries that are abundant in such resources. Put another way, government resource revenues are high in countries where nonrenewable natural capital is a large share of total wealth. Resource revenues in MENA countries can reach half of total revenues. And many countries in Sub-Saharan Africa have a high dependence on nonrenewable natural capital and resource revenues, including Gabon, the Republic of Congo, Chad, Guinea, Mozambique, and Nigeria (figure 9.6, panel a). Since nonrenewable wealth may be at risk from the low-carbon transition, countries' fiscal position—and governments' ability to finance development priorities—would likewise be placed at risk. These countries may

FIGURE 9.6 Nonrenewable Natural Capital and Natural Resource Revenue, Top Countries, 2018



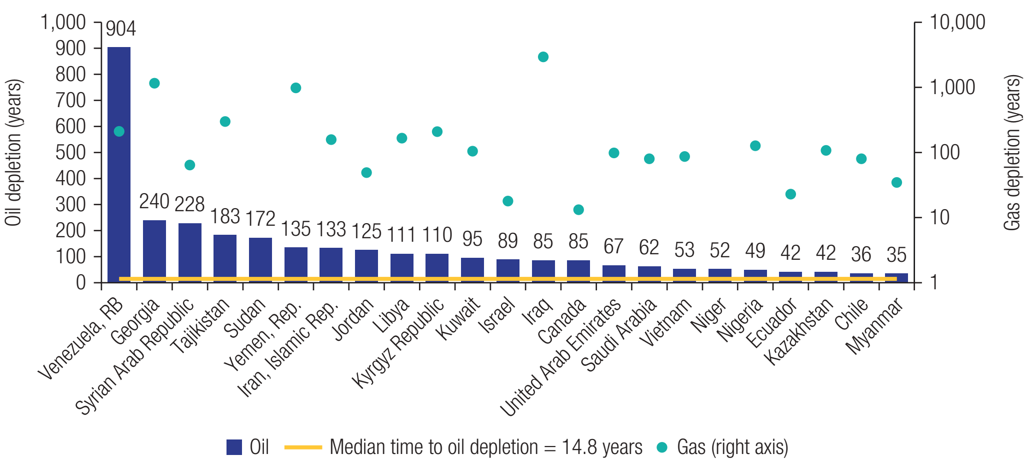
Source: ICTD/UNU-WIDER 2020; World Bank staff calculations.
Note: Some countries have missing resource revenues for recent years and are left blank in panel b.

need to start accelerating the transformation of their revenue sources to other sectors of the economy as associated assets—such as human, productive, and renewable capital—to avoid the potential negative consequences of reduced global demand for fossil fuels.

Potential for Reduced Revenues from Reserves Depletion and Exhaustion

Considering current amounts of fossil fuel reserves, 18 countries would have oil reserves that could last for more than two generations. According to the US Energy Information Administration's annual petroleum reserves and production data (EIA 2020), oil reserves in fossil fuel–dependent countries, such as the República Bolivariana de Venezuela and the Islamic Republic of Iran, could last for more than a century (figure 9.7). But other oil-producing countries, like Nigeria and Ecuador, could entirely deplete their oil reserves in fewer than 50 years at current depletion rates, assuming no other significant oil fields are discovered or become commercially viable. Natural gas reserves could last longer. However, some countries, such as Israel and Canada, might exhaust their gas reserves before they exhaust their oil reserves. Nonetheless, with the decarbonization efforts and the reduction in the prices of other sources of energy, much of these resources could become uncommercial with reduced importance in a nation's total wealth before full exhaustion is reached. The order in which reserves become stranded will likely be a function of the cost of production and world prices, among other factors.

FIGURE 9.7 Time to Depletion of Oil and Gas Reserves, 2018



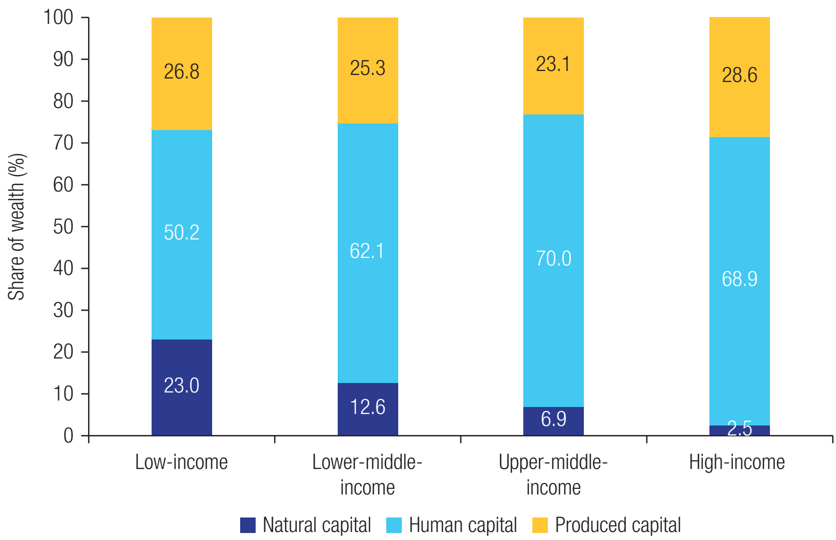
Source: World Bank staff calculations based on data from EIA 2020.
Note: Median time to depletion for oil is 14.8 years among 95 countries with oil production data. Depletion rates are calculated by dividing annual reserves data over annual oil or gas production numbers. Only countries with depletion horizons of more than 30 years and production above 1 million barrels per day are displayed.

Policies and Investments Increasing Low-Carbon Transition Risks

Many countries with high rents from nonrenewable natural capital have not invested sufficiently to offset the depleting asset. This is expressed in terms of negative adjusted net savings. This is true not only for hydrocarbon-rich countries, such as Iraq and Nigeria, but also for some mineral-rich countries, such as Guinea and Sierra Leone. The negative adjusted net savings in these countries is a lead indicator of unsustainable wealth management. If continued, it will negatively impact the value of future wealth. This is because the value of a depleting nonrenewable asset is being consumed rather than invested in offsetting asset accumulation—such as via human capital or productive capital investment. Therefore, governments may need to consider policies that would better preserve and build wealth or look for alternative sources of income to raise their net savings.

Investments in renewable natural capital and human capital could help countries to diversify their asset portfolio and reduce their dependence on nonrenewable natural capital. Peszko et al. (2020) suggest that an asset diversification strategy where a country invests in renewable natural capital and intangible assets, like knowledge, innovation, and institutions, could help reduce the exposure to low-carbon energy transition risks. They also suggest that this strategy increases the flexibility, resilience, productivity, and climate mitigation co-benefits. This is different from traditional diversification, in which nonnatural resource-intensive traded sectors are subsidized, which has been the prevailing growth model in many fossil fuel–dependent countries (Peszko et al. 2020). According to 2018 data, on average, low-income countries had the highest natural capital share of total wealth, which translates into a higher dependence on this type of wealth. By contrast, high-income countries had on average the lowest share of natural capital, indicating less reliance on this type of capital. In other words, on average, the higher the income level is, the lower is the share of wealth concentrated in natural capital. The natural capital share of total wealth in low-income countries could be five times higher than that in upper-middle-income countries (figure 9.8). Similarly, the higher the income level is, the higher is the human capital share of total wealth, consistent with the strategy proposed by Peszko et al. (2020). Chapters 11 and 12 explore in depth the asset diversification strategy and its implications for wealth and growth. Moreover, when a capital stock is low—human and physical capital in low- and lower-middle-income countries—the returns of investing in them can be higher (Venables 2016). These investments should not be independent of each other, because human and physical capital are interconnected; produced capital is more productive with more human capital, and human capital is more productive with better infrastructure or physical capital (de la Brière et al. 2017). Countries should use their natural resource rents to fund the accumulation of these other capitals, but the evidence suggests that these rents are not always reinvested successfully (van der Ploeg 2011).

FIGURE 9.8 Average Share of Wealth, by Type of Capital and Income Group, 2018



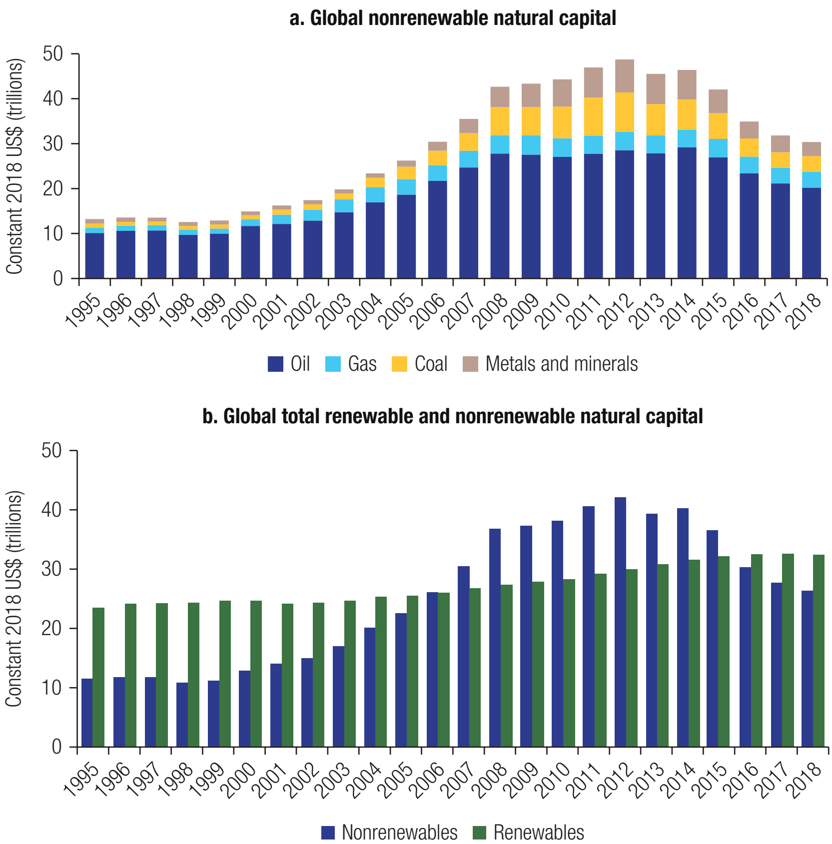
Source: World Bank staff calculations.

Diversification and Nonrenewable Natural Capital

The share of mineral wealth in total wealth has grown over the past two decades, compared with the share of fossil fuel wealth. Fossil fuel wealth has been the main source of nonrenewable natural capital for many years. However, during the 2008 financial crisis when oil prices dropped dramatically for the first time since the commodity boom started, the share of mineral wealth in total wealth started to grow more rapidly, while the share of fossil fuel wealth declined (figure 9.9). In 1995, global mineral wealth was only 8 percent of total nonrenewable natural capital; the remaining 92 percent corresponded to fossil fuel wealth. However, the commodity boom incentivized the exploration of new mines, which led to new discoveries that contributed to mineral wealth rising to 15 percent of total nonrenewable natural capital in 2012. When the commodity boom ended, mineral wealth did not decline as much as fossil fuel wealth, principally due to the oil price crash in 2014–15. The transition to new wealth sources has already started in countries like Brazil, the Democratic Republic of Congo, and Turkey. Figure 9.10 shows that before 2005, these countries had significant amounts of fossil fuel wealth, but in the past decade, mineral wealth overtook oil wealth, becoming the most important source of nonrenewable natural capital in these countries.

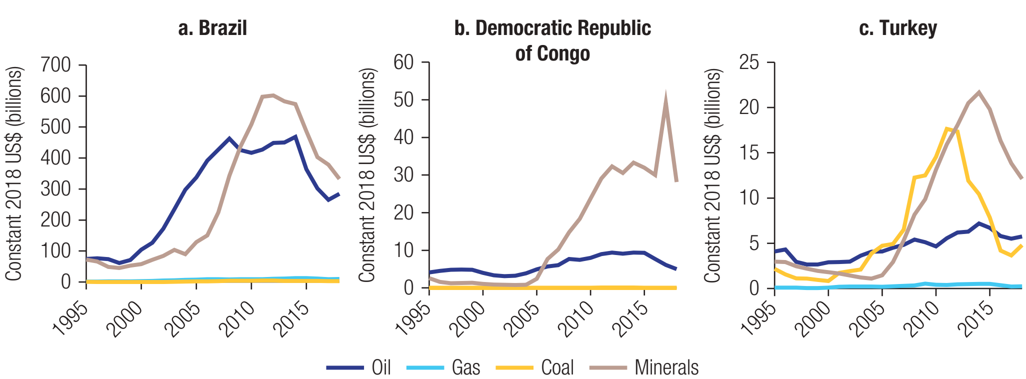
Globally, there is still a long way to go in the transition to a low-carbon energy scenario. Over the past two decades, fossil fuel wealth more than doubled, from about US$13 trillion in 1995 to about US$30 trillion in 2018, reaching a peak during the commodity boom. This situation reflects the scale of the challenge to decarbonize the global economy.

FIGURE 9.9 Global Nonrenewable and Renewable Natural Capital, 1995–2018



Source: World Bank staff calculations.

FIGURE 9.10 Nonrenewable Wealth in Brazil, the Democratic Republic of Congo, and Turkey, by Type, 1995–2018



Source: World Bank staff calculations.

Galeazzi, Steinbuks, and Cust (2020) argue that the so-called mineral energy materials may face upside market risks as the global economy increases demand for low-carbon technologies that are intensive in these minerals. However, estimates of trade elasticities suggest that to capitalize on this opportunity, many countries will need to become more responsive to increased demand or otherwise face intense competition from other established mineral producers.

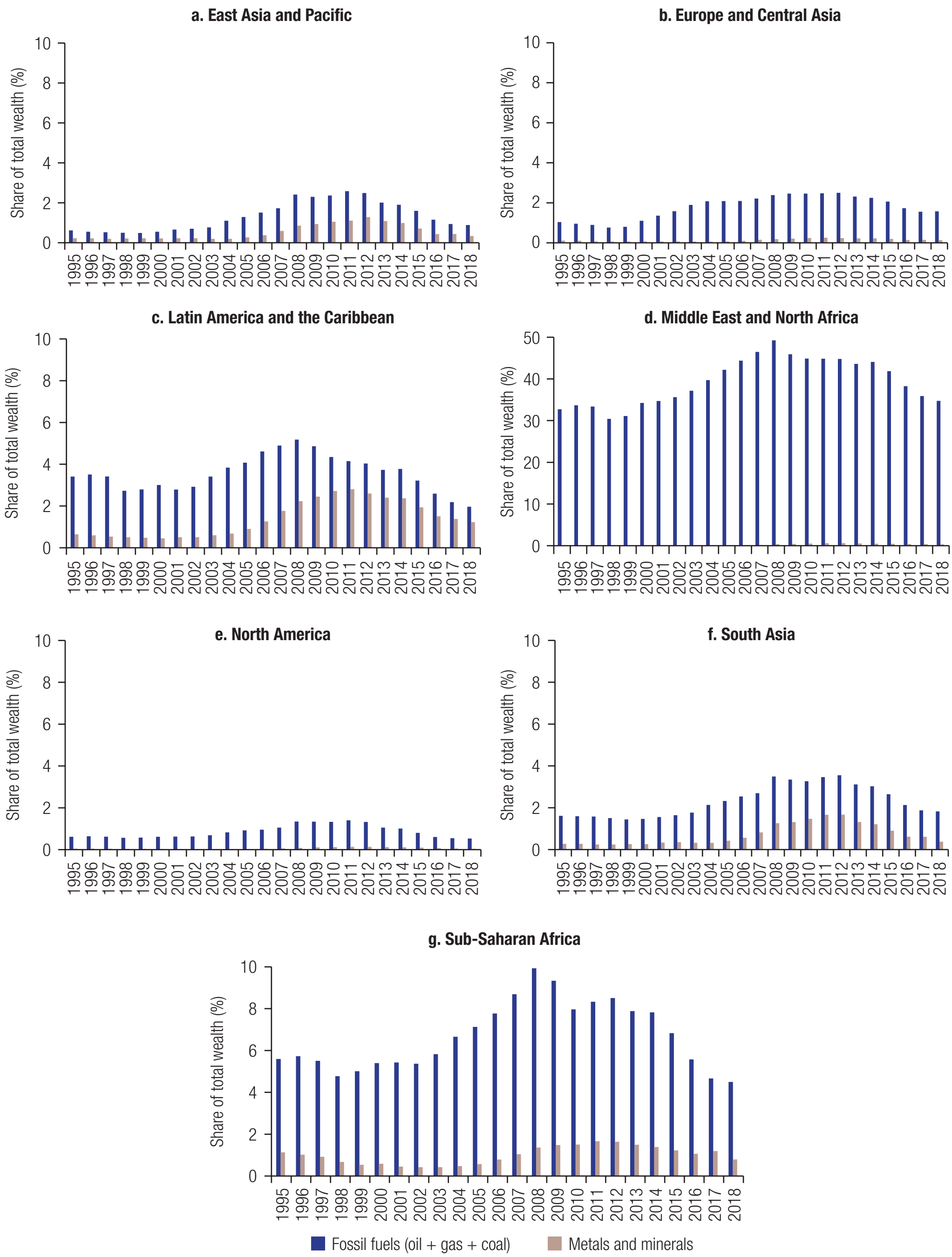
Global mineral wealth in 2018 reached US$3.1 trillion, still less than the US$3.4 trillion of coal wealth or the US$30 trillion of fossil fuel wealth in the same year. This means that global fossil fuel wealth in 2018 was 10 times the amount of mineral wealth. However, there is some extent of heterogeneity across regions. Fossil fuel wealth is the dominant type of nonrenewable natural capital in all regions of the world, but Latin America and the Caribbean has been the only region that has shifted this trend. As shown in figure 9.11, after the oil price shock of 2008, minerals became almost as important as fossil fuels in the region's total wealth. This region has the lowest difference between fossil fuel wealth share and mineral wealth share in the world. A higher share of mineral wealth may therefore provide some risk mitigation from the global transition away from fossil fuels.

Due to the low-carbon energy transition, the annual demand for five minerals is expected to increase by more than 100 percent over the next 30 years. However, there are still important uncertainties around the future of their demand. According to Hund et al. (2020), the demands for graphite, lithium, cobalt, indium, and vanadium are expected to more than double by 2050. In the case of graphite, lithium, and cobalt, which are needed to produce batteries, annual demand is expected to increase by almost 500 percent under a 2-degree Celsius global warming scenario. The demand for aluminum is projected to have a more modest increase of less than 10 percent, but the world will continue demanding more than 5 million tons of this metal annually to continue building lightweight technology and other new technology components. Figure 9.12 shows the projected annual demand for 17 minerals compared with annual production in 2018. All these minerals play a critical role in the low-carbon energy transition, and their demand is projected based on deployed battery technology. However, Hund et al. (2020) raise three main uncertainties around the future demand for these minerals: the mineral composition of new technologies, the amounts of these types of technologies deployed in the future, and which of the new technologies will actually be deployed.

Nonrenewable Natural Capital and the Environmental Kuznets Curve

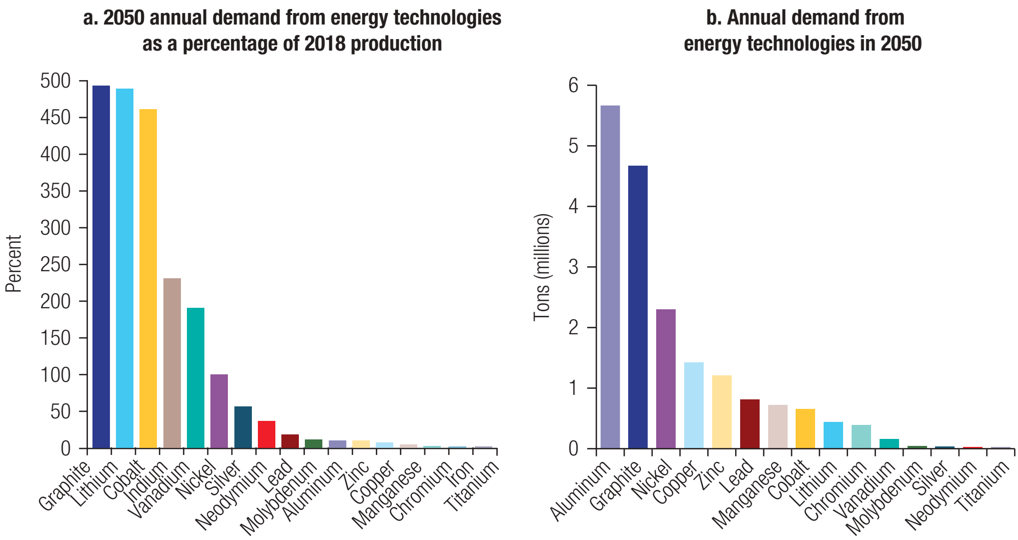
On average, the nonrenewable natural capital share of total wealth in low- and high-income countries is smaller compared with the share in middle-income countries. This forms an inverted-U shape, with low and rising shares at lower incomes, then transitioning to higher but declining shares at upper levels of national income.

FIGURE 9.11 Total Fossil Fuel and Mineral Wealth Share of Total Wealth, by Region, 1995–2018



Source: World Bank staff calculations.

FIGURE 9.12 Projected Annual Mineral Demand in 2050 from Energy Technologies under the 2-Degree Celsius Scenario Compared with 2018 Mineral Production Levels



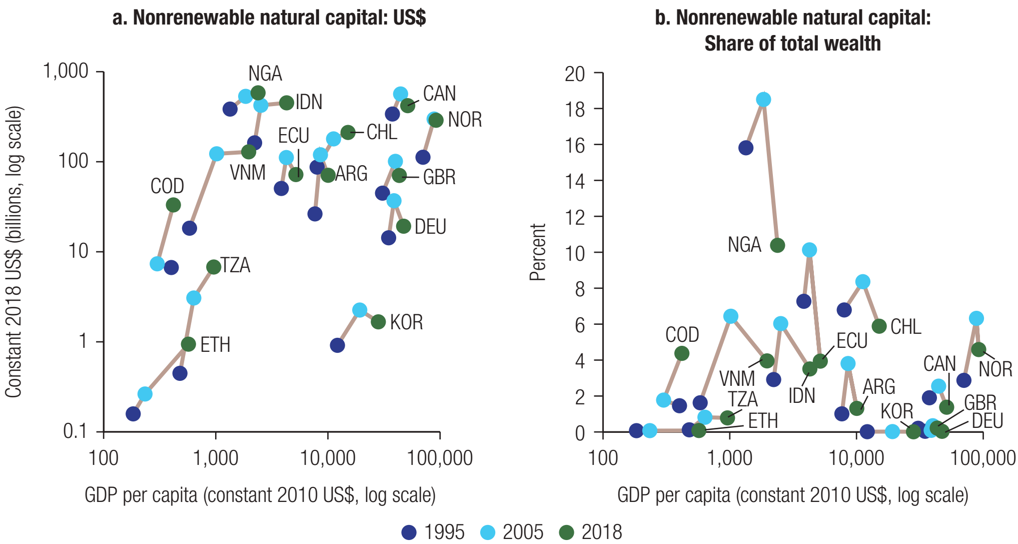
Source: Hund et al. 2020.

This inverted-U pattern is similar to the Environmental Kuznets Curve. The concept of the Environmental Kuznets Curve was introduced by Stern, Common, and Barbier (1996) to describe the supposed relationship between income change and environmental degradation. This concept is derived from the Kuznets Curve proposed by Kuznets (1955), who found that the relationship between income inequality and economic development follows the shape of an inverted-U. The Environmental Kuznets Curve proposes that environmental degradation first rises and then falls as income per capita increases.

This chapter finds that the relationship between nonrenewable natural capital and GDP per capita, considering all countries in the world, follow a similar inverted-U shape. According to 2018 data, countries with a lower GDP per capita, such as Ethiopia and Tanzania, had lower levels of nonrenewable natural capital (figure 9.13). Similarly, as countries experience rising incomes, moving to the right along the x-axis in figures 9.13 and 9.14, nonrenewable natural capital first increases and then declines. Between 1995 and 2005, the nonrenewable natural capital of countries like Ethiopia and Tanzania rose as their GDP per capita increased. But between 2005 and 2018, the growth rate of their nonrenewable natural capital diminished as their income per capita continued to increase.

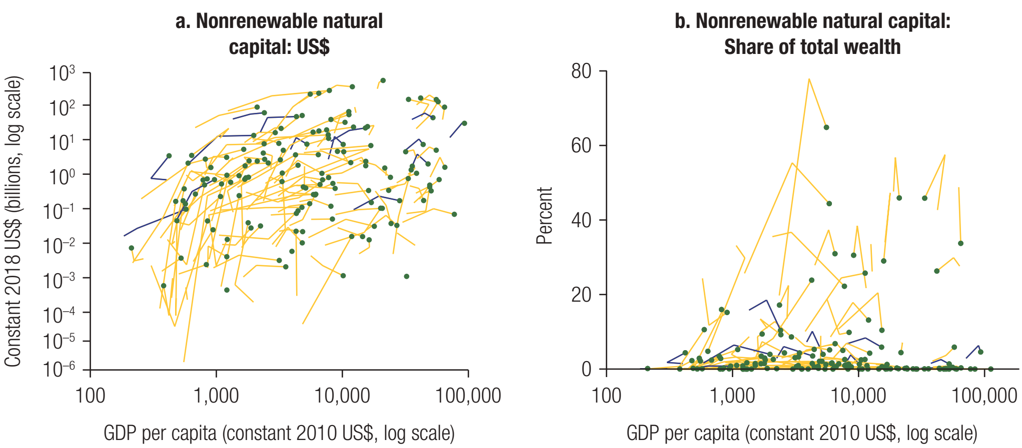
The relationship observed between rising income and an inverted-U shape in nonrenewable natural capital does not imply causality between the two. However, given the important role of nonrenewable wealth in driving increases in GDP per capita among poorer countries—whose

FIGURE 9.13 Kuznets Curve of Nonrenewable Natural Capital and GDP per Capita, Selected Countries at Different Income Levels



Source: World Bank staff calculations.

FIGURE 9.14 Kuznets Curve of the Nonrenewable Natural Capital and GDP per Capita, All Countries



Source: World Bank staff calculations.
Note: Yellow lines indicate changes between 1995, 2005, and 2018, where available. Blue lines indicate countries shown in figure 9.13.

wealth in other categories is much lower—it is perhaps unsurprising that the curve is upward-sloping at first. Likewise, given the important roles of structural transformation, industrialization, and human capital accumulation in explaining countries' graduation from middle- to upper-income levels, the declining importance of nonrenewable wealth is no surprise. Nonetheless, this relationship does reflect how resource dependence is not fate. Indeed, countries successfully achieving higher-income status have often done so with declining shares of resource wealth, rather than the opposite.

This relationship may be a useful guide for policy makers who seek to emulate the path of countries at aspirational levels of GDP per capita. It further underscores the declining importance of nonrenewable natural capital as countries move toward higher income levels, reflecting the faster rate of accumulation of other assets, such as human capital, productive capital, and the enhanced value of renewable natural capital. This is consistent with policy insights found elsewhere in this report—resource wealth can and should be used to enhance asset accumulation elsewhere in the economy. Revenues from resource extraction provide a special opportunity for governments to enhance other categories of wealth and to drive structural transformation of the economy.

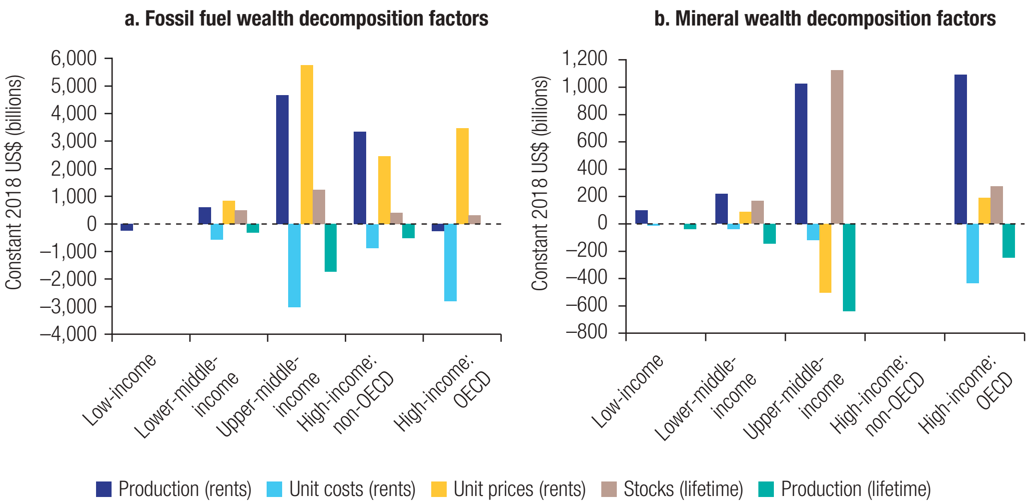
Decomposition Analysis: What Is Driving the Changes in Nonrenewable Natural Capital?

A decomposition analysis is useful to quantify the magnitudes of the different factors that are used to estimate the value of nonrenewable natural capital (Hoekstra 2021).[3]

The factors that produce changes in fossil fuel wealth are different from the factors that change mineral wealth. According to nonrenewable natural capital decomposition data, the five cumulative decomposition factors—production (rents), unit costs (rents), unit prices (rents), stocks (lifetime), and production (lifetime)—have changed the carbon and mineral wealth of nations in different ways. Nonrenewable natural capital in low-income and lower-middle-income countries has changed little, because these factors changed slightly compared with the other income groups. Nonrenewable natural capital has changed the most in the upper-middle-income group. On average, production has been the main factor increasing nonrenewable natural capital wealth for most countries, while increases in unit costs have been the main factor reducing it.

However, other factors have contrasting effects on carbon and mineral wealth. Fossil fuel wealth benefited from resource unit prices derived from the high oil prices during the commodity boom. But for mineral wealth, increases in resource stocks—for example, via discoveries—have been the main driver of wealth accumulation. This has happened mainly in upper-middle-income countries where most of the new mineral deposits have been found. The high exploration and investment costs to produce fossil fuel assets have negatively affected countries' nonrenewable natural capital, but they have had a smaller effect for mineral assets. Accelerating

FIGURE 9.15 Value of Cumulative Fossil Fuel and Mineral Wealth Decomposition Factors, by Income Group, 1995–2018



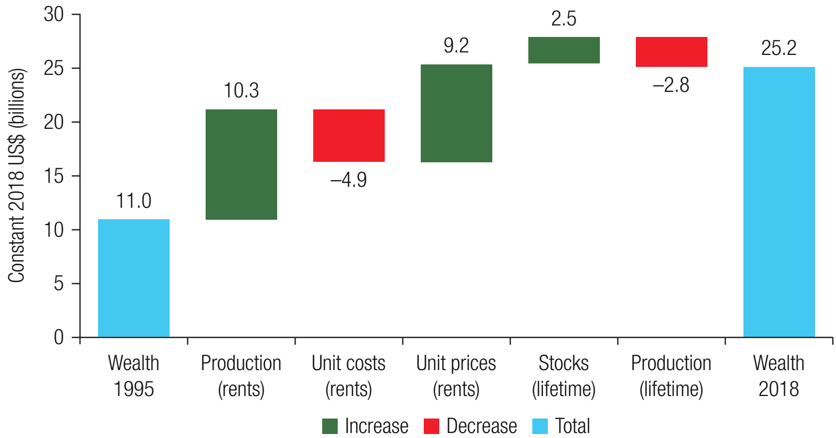
Source: World Bank staff calculations based on data from Hoekstra 2021.
Note: Bars show decomposition factors by income group according to World Bank classification. See Hoekstra 2021 for a detailed definition of decomposition factors.

mineral depletion has become the main factor reducing mineral lifetime production and mineral wealth. Figure 9.15 shows the magnitudes of the fossil fuel and mineral wealth decomposition factors between 1995 and 2018, by income group.

Over the past two decades, global nonrenewable natural capital has increased thanks in part to the production effect. However, fossil fuel wealth is at risk because of high unit costs, and mineral wealth is at risk because of high depletion rates. Nonrenewable natural capital has more than doubled, despite its finite nature, especially during the commodity boom. High commodity prices during the 2000s incentivized the production of nonrenewable natural capital and exploration for new reserves. This is illustrated by the large decomposition effects of production (rents) and unit prices, at US$10.3 billion and US$9.2 billion, respectively, in 2018 (figure 9.16). The main factor contributing negatively to the changes in wealth was the rising nonrenewable unit cost—the cost of getting the resource out of the ground. Increasing unit costs of extraction led to a US$4.9 billion reduction in fossil fuel wealth. The implication is that if unit costs continue to increase because of the growing complexity of oil and gas extraction, and if oil or gas prices continue declining, wealth will diminish significantly. Due to the drop in rents, some production projects might not be profitable and could be become stranded assets. The countries with the highest unit costs are most at risk of this development.

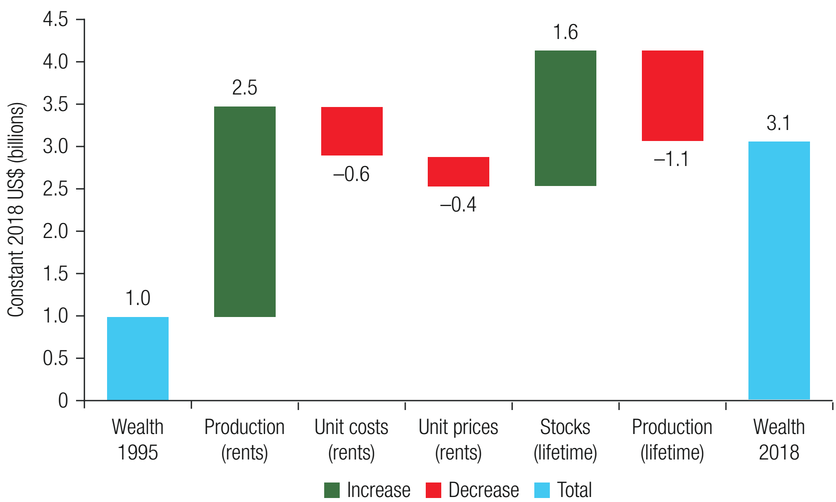
The 1995–2018 cumulative increase in mineral wealth was US$2.1 billion (figure 9.17). The increase was thanks to mineral production and

FIGURE 9.16 Decomposition of the Change in Fossil Fuel Wealth, 1995–2018



Source: World Bank staff calculations based on data from Hoekstra 2021.

FIGURE 9.17 Decomposition of the Change in Mineral Wealth, 1995–2018



Source: World Bank staff calculations based on data from Hoekstra 2021.

new discoveries expressed as lifetime stocks, so that mineral wealth tripled. A striking difference between fossil fuels and minerals is that the effect of unit prices is negative for minerals. That means that over this period, prices decreased and led to a decrease in wealth. However, looking at the detailed decomposition results shows that this trend is dominated by the effect of price changes in iron ore (about one-third of total mineral wealth). Bauxite and nickel wealth were also affected by negative unit price effects, but all the other mineral resources showed growing wealth due to price increases (see Hoekstra 2021 for details). The implication is that the mineral wealth of countries will be dependent on the type of mineral in question. Depending on the prospects for unit price, unit cost, production, and discoveries, countries can assess the prospects for declining or increasing mineral wealth. Some minerals, such as lithium and cobalt, are likely to benefit from a low-carbon future, while others may suffer.

Conclusion

Although nonrenewable natural capital accounts for just 2.5 percent of total wealth in the world, in monetary terms it is equivalent to more than one-third of the world's GDP. Many economies rely heavily on nonrenewable natural capital for export earnings and government revenues, a scenario sometimes referred to as *resource dependence*. Countries with high levels of dependence on nonrenewable natural capital already face several macroeconomic challenges associated with managing those assets and the volatile revenues they generate. However, they also face longer-term challenges—such as the global low-carbon energy transition—that might jeopardize the future value of their wealth.

Over the past two decades, many countries have taken advantage of high commodity prices and increased the depletion rates of their nonrenewable natural capital. However, despite high levels of production, and significant revenues generated by this production that could be invested in other forms of wealth, nonrenewable wealth remains a significant share of total wealth in many countries. In fact, despite being a depleting resource, the nonrenewable wealth of nations more than doubled between 1995 and 2018, from US$13 trillion to US$30 trillion.

Overreliance on nonrenewable natural capital, however, has proven risky. Price drops since 2014 have seen nonrenewable wealth crash by 35 percent in just four years—down from US$46 trillion to US$30 trillion by 2018. In addition, unit costs have increased because extraction of nonrenewable natural resources has become more difficult. Nonrenewable resource–rich countries have failed to diversify their asset base; instead, many have seen a rising concentration in their wealth accounts. This may prove challenging as countries face new risks on the horizon.

The low-carbon transition may significantly alter the demand for and prices of fossil fuels that emit carbon dioxide. It may also alter the demand for metals and minerals required for low-carbon technologies such as batteries and wind turbines. There may be falling rents available to fossil fuel–rich countries in the future and uncertainty in the demand for different minerals and metals as new technologies are adopted or become obsolete. This means there is an even greater premium on a diversified asset portfolio designed to increase resilience to future risks and the ability to achieve sustainable prosperity.

Annex 9A: Methodology for Valuing Nonrenewable Natural Capital

The Changing Wealth of Nations (CWON) *2021* follows the same conceptual approach to valuing nonrenewable natural capital as CWON 2018 (Lange, Wodon, and Carey 2018). As described in Cust and Manley (2018), the value of a nation's stock of nonrenewable natural capital is measured as the present value of the stream of expected total rents that may be extracted from the resource until it is exhausted. Implementing this approach requires (1) estimating rents and (2) projecting the future flow of rents. Due to the high volatility of commodity prices and rents, smoothing rents over a period of five years or so could provide a better indication of long-term value, the aim of wealth accounting.

Under the current CWON implementation, asset value, V_t, is given as

$$V_t = \sum_{i=t}^{t+T-1} \frac{\overline{R_t}}{(1+r)^{i-t}}, \tag{9A.1}$$

where

$\overline{R_t}$ = lagged, five-year moving average of annual total rents, R_t, in years t (the current year) to $t - 4$,
r = the discount rate (assumed to be a constant 4 percent), and
T = the lifetime of the resource.

Total rents in the current year are calculated as

$$R_t = \pi_t q_t, \tag{9A.2}$$

where

π_t = unit rents and
q_t = quantity of resources extracted.

Unit rents, π_t, in year t are calculated as

$$\pi_t = (p_t - c_t), \tag{9A.3}$$

where

p_t = average unit price,
c_t = average unit production costs including a "normal" rate of return on fixed capital and the consumption of fixed capital.

Rents, R_t, are converted into constant US dollars at market rates using country-specific gross domestic product deflators before averaging to obtain $\overline{R_t}$. $\overline{R_t}$ averages unit rent and quantity.[4]

While rents are expected to capture the estimated compensation from resource extraction in a country, they may represent only an upper bound of the volume of rents that a government actually succeeds in taxing or otherwise capturing from the extraction of these resources (Cust and Manley 2018).

Notes

1. While this risk is measured using current levels of reserves—and in this report, levels of fossil fuel wealth—it is likely that significant fossil fuel resources remain undiscovered. Recent research suggests the undiscovered resources may be concentrated in countries with historically weaker political institutions, which skews toward lower-income countries (Cust and Harding 2020). For this reason, estimates of the scale of risk faced by these countries may constitute a lower bound compared to their true level of fossil fuel deposits, many of which are yet to be found.
2. Although some international organizations make predictions about future commodity prices, deep uncertainty exists given the complexities of the demand and supply for these resources. Economic theory has in the past proposed methods for forecasting future oil prices, such as the Hotelling Rule. However, these methods proved to have limited predictive power during the 20th century. Furthermore, with expectations around future climate policies and competition in energy technologies driving falling costs, the prospects for future prices are even more uncertain.
3. For technical details on how the decomposition analyses are calculated, please see Hoekstra (2021).
4. This approach will be revised in the future to smooth only the unit rents, not total rents. The lagged average unit rent will be applied to annual production, unsmoothed.

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10

Low-Carbon Transition, Stranded Fossil Fuel Assets, Border Carbon Adjustments, and International Cooperation

Grzegorz Peszko, Dominique van der Mensbrugghe, Alexander Golub, and Maksym Chepeliev

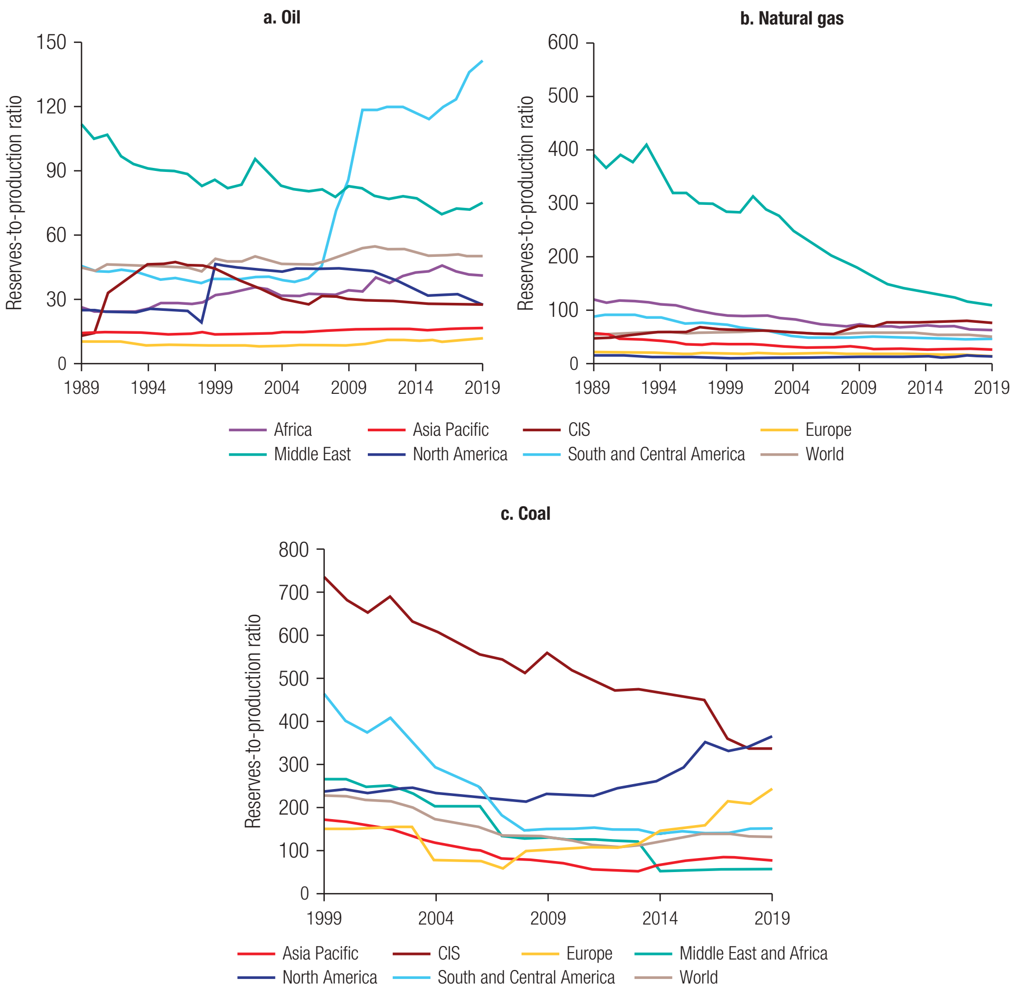
Main Messages

- A low-carbon transition represents a material risk to the value of all fossil fuel assets. In the 2018–50 period, global fossil fuel wealth may be US$4.4 trillion to US$6.2 trillion (13 to 18 percent) lower than in the reference scenario, depending on the ambition level of global climate policies.
- The distribution of risk across fuels, countries, and asset owners depends on initial conditions, such as the fuel type they depend on, costs of production, market power and exposure of the rest of the economy to this risk, and on policy pathways—whether they are cooperative or not and whether free riding will meet border carbon adjustment taxes (BCATs) or not.
- Net fuel importers have incentives to lead on climate policies and apply BCAT against fuel exporters to encourage their cooperation. Oil wealth benefits from cooperative climate action, while gas exporters may benefit from free riding and leakage, even facing BCATs. High carbon prices would significantly reduce the wealth of coal producers, whether they cooperate or not, but macrofiscal risk for coal-intensive countries is small—stranded power plants and people in mining regions are a bigger challenge.
- Lower-income, fragile, and conflict-affected fossil fuel producers may need assistance in the low-carbon transition if they have not yet converted underground energy wealth to produced capital in the manufacturing sector and have limited alternative assets (human and natural) to support growth.

Introduction

Fossil fuels will not run out anytime soon. During the past century, depletion of known oil, gas, and coal reserves has been compensated by new discoveries and progress in extraction technologies. Each time the expected scarcity pushed the resource prices up, the markets responded by accelerating technological innovation and exploration. New extraction technologies made production cheaper, bringing to markets new reserves that were previously commercially unrecoverable, such as shale oil and gas or deepwater oil fields. Over the past 30 years, the world's reserves-to-production ratios for oil and natural gas have remained fairly constant (figure 10.1).

FIGURE 10.1 Reserves-to-Production Ratios for Oil, Gas, and Coal over the Past 30 Years



Source: BP 2020, 15, 33, 45. Used with permission; further permission required for reuse.
Note: BP uses the concept of "proved reserves" as "those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing conditions." CIS = Commonwealth of Independent States (Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyz Republic, Moldova, the Russian Federation, Tajikistan, Turkmenistan, and Uzbekistan).

But the planet is running out of space to burn fossil fuels. Using all known fuel reserves that can be commercially extracted under reference conditions would lead to the accumulation of greenhouse gasses in the atmosphere. There is a high probability that this would cause excessive climate-related risks (United Nations Framework Convention on Climate Change). Crucially, the world cannot rely on markets to self-correct economic activities when the concentration of greenhouse gasses in the atmosphere becomes too high in the same manner that fossil fuel prices inform investors and consumers when the fossil fuel reserves in the ground become too low. Climate change and other environmental impacts are "external" to markets. Global warming does not trigger an automatic increase in fossil fuel prices to inform economic agents that their consumption is excessive. Policies must do this job.

Government policies can put visible prices and other constraints on carbon embedded in fossil fuels and alter the market conditions for their extraction and use. Internalizing climate cost into the prices of fossil fuels would accelerate peak demand for them by encouraging substitution into alternative energy technologies. This in turn would render extraction of some reserves no longer commercially viable. Some oil, gas, and coal reserves that currently are commercially recoverable would no longer yield the expected economic benefits to their owners. Their value could drop, potentially reducing the contribution to national wealth reflected in *The Changing Wealth of Nations* (CWON).

Valuing assets is a forward-looking exercise. The value today of economic assets is an *expected* flow of future economic benefits to the owners and operators. The stranded assets literature has raised the alarm that low-carbon transition, whether induced by policies, technologies, or consumer preferences, may cut these economic benefits well short of expectations. If the goals of the Paris Agreement were to be achieved, future fossil fuel consumption would have to be much lower than in the past. But how exactly this future will unfold, when and where the policy and technology tipping points will materialize, is uncertain. This uncertainty is unfortunately deep, meaning that the probability distribution of different drivers of the value of fossil fuel assets is unknown or cannot be agreed upon among the key stakeholders who shape the future development pathways.

This chapter explores this uncertainty by stress testing the expected values of fossil fuel assets under alternative policy pathways to reach the goals of the Paris Agreement.[1] This question is not new in the literature and public debate. There are, however, a few novel contributions that this chapter aims to add to the existing knowledge. First, it explores risks to the valuation of fossil fuels in terms as closely related as possible to rigorous System of National Accounts (SNA) and System of Environmental-Economic Accounting (SEEA) accounting standards, rather than relying on assets as a metaphor. Second, it applies an economywide, global, recursive dynamic macroeconomic model rather than focusing on extractive sectors in isolation and assuming perfect foresight. Third, it applies a wider range of low-carbon transition policy scenarios than most models used in the stranded assets literature.[2] Fourth, it informs the political economy of international climate cooperation by exploring how the distribution of stranded assets across regions changes in alternative climate and trade policy scenarios.

Valuing Subsoil Fossil Fuel Assets in the CWON

Not all known and proven reserves qualify as economic assets. In the SNA, only the deposits that are commercially exploitable, given current technology and relative prices, are considered assets (EC et al. 2009). SEEA identifies three classes of known deposits, among which only "class A," commercially recoverable resources that come from on-production projects, projects approved for development, and projects justified for development, is recommended for inclusion in the balance sheets (United Nations 2019, 93). The CWON follows these recommendations in its valuation of fossil fuel reserves. In contrast, the stranded assets literature, especially the "gray" literature, often considers a much wider scope of reserves as being potentially "stranded assets," using the concept of asset as a metaphor rather than a balance sheet concept (Carbon Tracker Initiative 2011). Within the CWON/SNA approach, all known or proven recoverable reserves cannot be "stranded assets," because a large portion of them are not assets in the first place. It is uncertain whether they would be extracted and converted into economic wealth even in the reference scenario. Leaving resources in the ground is not new to extractive industries. For example, IEA (2013) shows that 60 percent of known coal reserves are left underground even in the business-as-usual scenario.

Expected returns determine asset value. The SNA and SEEA provide a recommended methodology for valuing commercially recoverable subsoil assets: the discounted sum of expected rents over the lifetime of an asset. In this approach, the asset value is determined by several factors, which can change resource rents in the future: the size of commercially recoverable reserves, the extraction path, prices, extraction costs, and interest rates. Since such forward estimates are not generally available for national accounts, the guidance from the SNA and SEEA is to assume that current or recent values for the factors that determine resource rents will remain constant into the future.[3]

The CWON core accounts apply the SNA and SEEA recommendations for the valuation of minerals and fossil fuels. Asset values are calculated with a five-year lagged average unit rent over the lifetime of the reserve of the resource or 100 years, whichever is less, and discounted with a constant 4 percent rate. For 2018, the last year for which annual resource rents were calculated, the five-year moving average covers the period of historically low fossil fuel prices following a significant drop in 2014. Therefore, constant future rents extrapolated from this five-year period are significantly lower than typically expected by resource owners. This implies that the traditional accounting methodology applied in the

CWON core accounts may lead to estimates of total fossil fuel wealth today that are somewhat conservative compared with what countries and companies are planning to realize. Even those conservative estimates help identify some fossil fuel wealth at risk across different fuels, regions, and countries. Furthermore, comparison of alternative policy scenarios with the reference policy pathway that is consistent with nationally determined contribution (NDC) commitments finds significant losses of fossil fuel wealth globally.

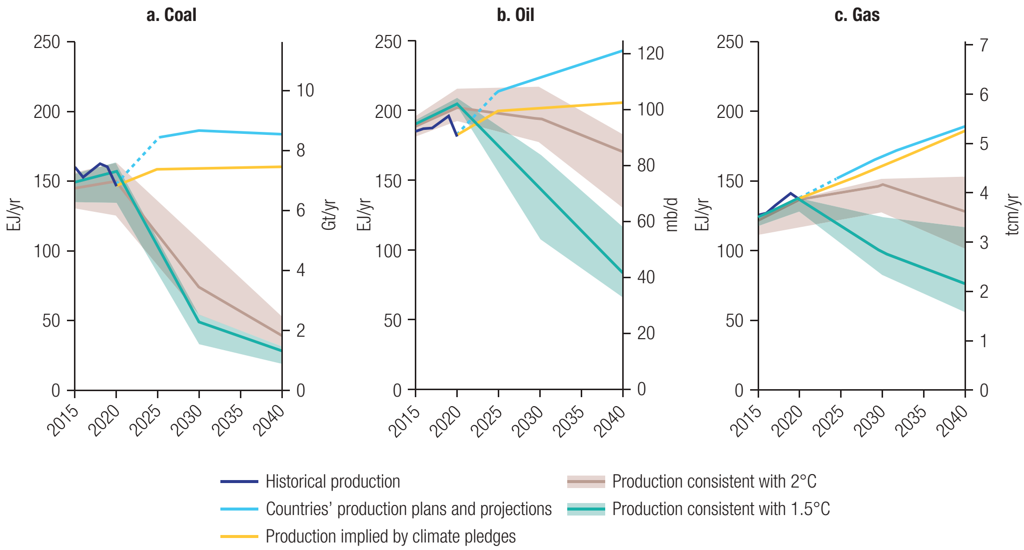
The historical values of oil, gas, and coal rents were calculated using multiple sources cross-checked for consistency. The value of national oil and gas reserves for 146 countries was compiled from the field-level data extracted from the Rystad database for production costs. Rystad was also used to calculate rental rates—unit price minus unit cost divided by unit price—with fossil fuel prices taken from the World Bank Commodities Price Data. Extraction data are from Rystad, the International Energy Agency (IEA), *BP Statistical Review of World Energy*, the US Energy Information Administration (EIA), and the United Nations *Monthly Bulletin of Statistics*. Proved reserves were taken from the *BP Statistical Review of World Energy* and the EIA.[4]

The CWON approach to valuing fossil fuel assets is a useful starting point for national balance sheets, but to understand the potential impacts of climate mitigation measures on the future of fossil fuel rents, it is not enough to assume that all the factors determining asset value remain constant. Therefore, this chapter complements the CWON core account estimates with model simulations of alternative profiles of future rents that may accrue to fossil fuel owners under the uncertain policy pathways of the low-carbon transition.

Valuation of Fossil Fuel Assets with the ENVISAGE v10 CGE Model

The uncertainty about the policy pathways to a carbon-neutral global economy and the tipping points for fossil fuels is *deep*. Expectations of different actors differ fundamentally, so—in technical terms—a probability distribution cannot be assigned to different future values of fossil fuel assets, because it is unknown or cannot be agreed by relevant stakeholders. The projections of production volumes, prices, and costs differ dramatically even for 2025 and 2030 (figure 10.2). Given the uncertainty about the future of fossil fuels, fewer and fewer organizations focus on projecting or forecasting future demand. Those who still do include the Organization of the Petroleum Exporting Countries and the EIA. Most, including the IEA and oil majors, have instead switched to foresights or scenarios for “exploring different possible futures, the levers that bring them about and the interactions that arise across a complex . . . system” (IEA 2018, 23). Developing several exploratory scenarios based on the plausible narratives about the future drivers of resource rent is the simplest way to inform decisions under such deep uncertainty (Ansari and Holz 2020; Peszko et al. 2020) and is applied in this study.

FIGURE 10.2 Fossil Fuel Production Gap: The Difference between National Production Plans and Low-Carbon (1.5°C and 2°C) Pathways, 2015–40



Source: SEI et al. 2020, 15.
Note: EJ = exajoules; Gt = gigatons (billion tons); mb/d = million barrels per day; tcm = trillion cubic meters; yr = year. Physical units are displayed on the secondary axes.

This chapter presents simulations of the values of oil, gas, and coal assets under alternative policy scenarios that can help reach the main goal of the Paris Agreement. The model is run in simulation and not optimization mode. This means that no particular emissions pathways or carbon budgets are assumed as constraints in the model. Instead, several cooperative and noncooperative carbon tax trajectories are run. The highest carbon taxes for which the model could find a solution for all policy scenarios produced cumulative carbon dioxide (CO_2) emissions (carbon budget) of 862 gigatons (Gt) of gross CO_2 emissions over 2018–50. Because (as expected from economic theory) the model could achieve deeper decarbonization with cooperative taxes only, next—as a sensitivity analysis—several iterations are run with higher cooperative carbon taxes. The cumulative gross emissions associated with the highest carbon tax trajectory for which the model could solve was 777 Gt CO_2 over 2018–50. Optimization approaches to scenarios that are dominant in the literature use a much wider variety of carbon budgets and emissions pathways (see Huppmann et al. 2019; Rogelj et al. 2019; Rogelj, Popp, et al. 2018; Rogelj, Shindell, et al. 2018 for more results).

The section on emissions results compares carbon budgets produced with the policy simulation approach to carbon budgets assumed or produced with the optimization approach available in the literature. It shows that the cumulative emissions produced by the scenarios are in line with the carbon budget used in the 2 degrees Celsius (°C)–consistent mitigation pathways and even some 1.5°C-consistent scenarios found in literature related to the Intergovernmental Panel on Climate Change (IPCC). The scenarios are simulated using the global, recursive, dynamic computable general equilibrium (CGE) model ENVISAGE v10 integrated with a dynamic and detailed resource depletion module calibrated to the global oil and gas extractive model Rystad UCube. The ENVISAGE model (van der Mensbrugghe 2019) is based on the Global Trade Analysis Project Power 10 database, containing a consistent set of social accounting matrices and energy balances for 141 world regions (Aguiar et al. 2019; Chepeliev 2020). The recursive and dynamic nature of the ENVISAGE v10 model used in this study represents decision-making in a dynamic setting under imperfect foresight. Such an approach allows accumulation of vulnerable capital stock based on the reference market conditions and expectations before the policy or technology shocks occur. Few stranded asset studies allow for myopic expectations and even fewer simulate dynamic, path-dependent processes (Mercure et al. 2018; Peszko, van der Mensbrugghe, and Golub 2020; Van der Ploeg and Rezai 2019).

The CGE perspective captures the economywide feedback loops and adjustments across sectors of the economy rather than just the direct impact in extractive industries and carbon-intensive sectors. Studies based on partial equilibrium or bottom-up models, prevailing in the stranded assets literature, do not capture these economywide spillover effects and feedbacks. They count capital released from industries affected by climate policy as fully stranded, while the general equilibrium framework more realistically allows a portion of this capital to be recycled into other sectors and still be productive.

For the purpose of this study, ENVISAGE was equipped with an endogenous oil, gas, and coal extraction module. This module includes three categories of oil, gas, and coal reserves: (1) unproven reserves, (2) proven reserves, and (3) the fraction of proven reserves that is brought to production if market conditions allow. The model mimics interactions between the fossil fuel supply and demand, which ultimately drives the production from fossil fuel reserves and market prices of fuel commodities. In unfavorable market conditions for a country (low demand and prices or high extraction costs), the extraction module suppresses production from its proven reserves, leaving some of them in the ground. When market conditions for this country become favorable, the module increases production of its previously underexploited proven reserves (if any) and converts some of its unproven reserves to proven ones. The supply and depletion functions have country-specific elasticities.

This model did not use induced technology progress through expenditures on research and development, as in Peszko, van der Mensbrugghe, and Golub (2020). As shown there, it could have a major impact on fossil fuel asset value in both directions, depending on how the public expenditure is targeted (to subsidize fuel use or innovation). Green technology policies are mimicked by the set of learning curves and preference parameters that were set in all scenarios (including the reference scenario) to accelerate the rates of penetration of clean technologies in the power, industry, and transport sectors.

The oil, natural gas, and coal rents are calculated endogenously in ENVISAGE. The resource rent is what is paid to the “flow” of the natural resource as it is transferred from the ground into the economy. In keeping with SEEA/SNA and CWON principles, unit resource rents are the difference between the market price and all variable costs—intermediate inputs, labor, and normal profits. Because ENVISAGE was calibrated to 2014, the asset values in 2018 that are calculated by the model deviate from those estimated in CWON for 2018. To facilitate comparison of results, the trajectory of rents attributed to oil, gas, and coal assets from ENVISAGE is normalized to the corresponding 2018 rent values estimated in the CWON and used to simulate the changes in resource rents over time. This method combines the comparative advantage of the CWON/SEEA methodology in estimating asset values in the past with the comparative advantage of the modeling approach to simulate alternative futures. Further details on ENVISAGE can be found in the underlying CWON technical report and online.[5]

Simulation of Subsoil Fuel Asset Values under Uncertainty

The goal of model simulation is not to predict the future value of the fossil fuel assets but to explore a range of alternative plausible policy futures. A set of exploratory scenarios represents uncertainty about how the key drivers of asset values will evolve. The simplest way to represent deep uncertainty is to build alternative scenarios from several combinations of a range of potential external impacts and strategic national policy choices. Constructing a range of future scenarios provides an opportunity to identify policy and asset management decisions that make the portfolio value robust to external shocks under the plausible worst-case futures. For clarity of argument, the range of scenarios has been limited and does not pretend to represent all plausible futures. A wider range of policy pathways to a low-carbon transition can be found in Mercure et al. (2018); Peszko, van der Mensbrugghe, and Golub (2020); and Van der Ploeg and Rezai (2019). The worst-case scenarios simulated were identified by ramping up the level of ambition of cooperative and noncooperative climate policies, respectively, until the CGE model could find an equilibrium solution. This can be interpreted as the numerical limit of the current model specification or the limits to the growth-focused neoclassical economics.

This study focuses on the distribution of risk to fossil fuel wealth across fuels and country groups and explores whether this distribution depends on the policy pathways to a low-carbon economy. Such a focus can inform the political economy of international cooperation on climate change. A set of unique narratives has been developed to underpin scenarios of alternative policy pathways toward the goals of the Paris Agreement. These narratives stress two critical dimensions of low-carbon transition: (1) whether it will be smooth and cooperative or disorderly and unilateral, and (2) whether noncooperation will be punished by border carbon adjustment measures or not. These narratives were first elaborated in Peszko et al. (2020) and were tailored specifically for this chapter to be simulated with the updated and enhanced ENVISAGE v10 and its new extraction module. The narratives are broadly consistent with the Network for Greening the Financial System scenarios for transition risk (NGFS 2020).

In the climate policy scenarios, the value of stranded assets (net present value of resource rents produced endogenously in the model) is calculated as the difference in the asset values against the reference scenario rather than against the CWON. Many investors and asset owners expect that future fossil fuel prices will be higher than those prevailing over 2014–18, which are used in the CWON for rent extrapolation. The more recent price shock caused by the COVID-19 lockdowns is not expected to keep fossil fuel prices low for too long. Therefore, asset owners often consider most of their economically proven but not yet commercially recoverable reserves as assets—more than could be put on the national balance sheet by conservative SNA standards. The asset owners expect that a large share of these proven reserves will be brought into production in the future and will generate rents. The reference scenario that assumes adherence to climate mitigation commitments officially pledged by countries through their NDC submissions better reflects such expectations than the CWON with its constant extraction and rent profile. It is common that national statistical offices assign lower values to national fossil fuel reserves in government balance sheets compared with the more wishful thinking of extractive companies and other agencies that exercise ownership rights over fossil fuel reserves. The policy scenarios simulated here represent surprise policy shocks that diverge fossil fuel prices and volumes away from those expected in the reference scenario and, hence, change the rent profiles compared with those expected by fuel owners. Sometimes the resulting rents (for example, for coal) are even below those that a conservative accountant would put into the national balance sheet from the CWON accounts.

Countries and Country Groups

For simulation purposes, the countries were aggregated into two stylized climate policy "clubs": (1) *climate policy leaders (CPLs)*, the members of which are assumed to be the likely primary movers of climate mitigation policies, and (2) *fossil fuel–dependent countries* (FFDCs), which choose to cooperate with CPLs on climate mitigation or free ride on their policy effort, risking BCATs. The results are reported for eight subgroups (table 10.1). The full list of countries in each category can be found in the background technical paper (Peszko et al. 2021).

Fossil fuel wealth is highly concentrated. As much as 80 percent of the global fossil fuel wealth, reaching US$26 trillion in 2018, is in three country groups: Middle East and North Africa (MNA); Europe and Central Asia (ECA); and the coal-intensive middle-income fuel importers, including China and India (figure 10.3). MNA itself accounts for over 50 percent of the world's total fossil fuel wealth.

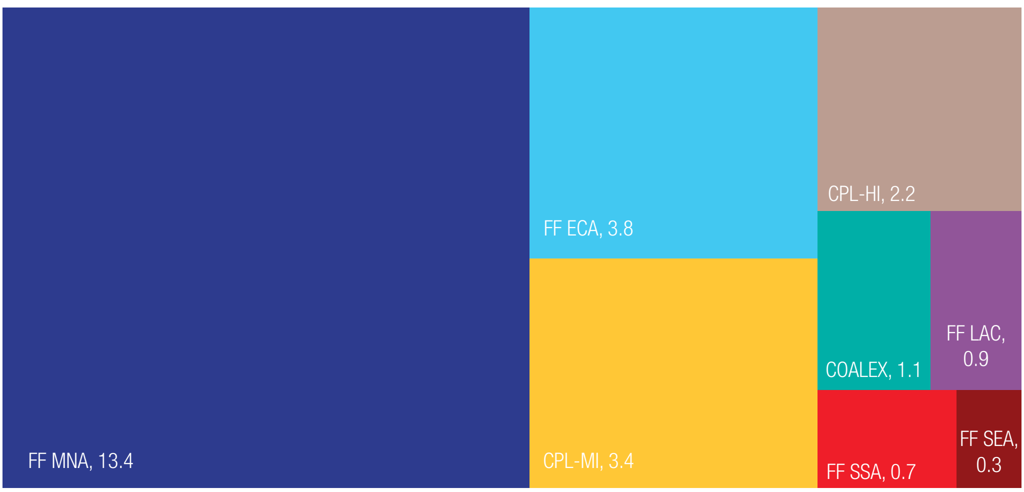
Countries depend on fossil fuels in many ways. Countries are also differently prepared for the impacts of low-carbon transition (see Peszko

TABLE 10.1 Climate Clubs

Climate policy leaders (CPLs)	Fossil fuel–dependent countries (FFDCs)
1. CPL-HI: high-income countries in the European Union, Canada, Norway, the United States, and other high-income fossil fuel importers 2. CPL-MI: low- and middle-income fossil fuel importers and often large coal users, including middle-income and lower-middle-income countries, such as Argentina, Brazil, Cambodia, China, India, the Lao People's Democratic Republic, Pakistan, the Philippines, Thailand, Turkey, Ukraine, and many others	3. FF MNA (Saudi Arabia + GCC + rest of oil and gas exporters in MNA) 4. FF ECA (Russian Federation + Caucasus and Central Asia) 5. FF SSA (Sub-Saharan Africa) 6. FF LAC (Latin America and the Caribbean) 7. FF SEA (Southeast Asia) 8. COALEX (coal exporters: Australia, Colombia, Indonesia, Mongolia, and South Africa)

Source: World Bank.
Note: ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); GCC = Gulf Cooperation Council; HI = high-income; LAC = Latin America and the Caribbean; MNA = Middle East and North Africa; SEA = Southeast Asia; SSA = Sub-Saharan Africa.

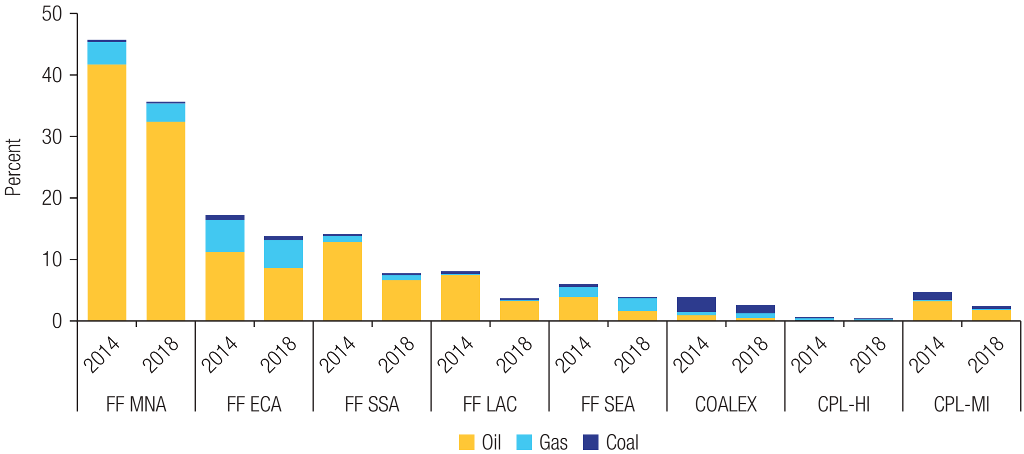
FIGURE 10.3 Value of Fossil Fuel Subsoil Assets, by Region, 2018
2018 US$ (trillions)



Source: World Bank staff calculations, http://www.worldbank.org/cwon/.
Note: COALEX = coal exporters; CPL = climate policy leaders; ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); HI = high-income; LAC = Latin America and the Caribbean; MI = low- and middle-income; MNA = Middle East and North Africa; SEA = Southeast Asia; SSA = Sub-Saharan Africa.

et al. [2020] for the index of preparedness for low-carbon transition). Figure 10.4 uses the CWON database to illustrate that, in the eight country groups, the share of fossil fuel wealth in total wealth in the FFDCs is higher than in the net fuel importers that are assumed to be the global CPLs. Oil accounts for the lion's share of total fossil fuel wealth and is the major source of systemic risk in the most fossil fuel–dependent countries. Gas plays a disproportionate role in the wealth of ECA. Coal is always a small part of total wealth and accounts for the

FIGURE 10.4 Share of Fossil Fuel Assets in Total Wealth in the CWON Core Accounts, by Country Group, 2014 and 2018



Source: World Bank staff calculations, http://www.worldbank.org/cwon/.
Note: COALEX = coal exporters; CPL = climate policy leaders; ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); HI = high-income; LAC = Latin America and the Caribbean; MI = low- and middle-income; MNA = Middle East and North Africa; SEA = Southeast Asia; SSA = Sub-Saharan Africa.

large share of total fossil fuel wealth in only two country groups—coal exporters and middle-income CPLs (mainly China and India). In all the country groups, the relative importance of fossil fuel wealth decreased after the 2014 fossil fuel price shock.

Scenario Analysis to Represent Risk and Uncertainty

The reference scenario assumes that countries will implement their unconditional NDCs, followed by four policy scenarios with assumptions about alternative climate and trade policy pathways to low-carbon transition (table 10.2). Climate policies are represented by economywide carbon taxes (shadow carbon prices) with rates calibrated to reach the goals of the Paris Agreement. The cumulative gross emissions of CO_2 in the modeling period calculated by the model are shown in the last column of table 10.2. They are gross, because they do not include unproven climate mitigation methods, such as carbon capture and storage (CCS) on fuel combustion installations, CO_2 removal (CDR) methods (so-called negative emissions), or geoengineering. Non-CO_2 gasses are also not included. After correcting for the impacts of these assumptions, the cumulative emissions produced by the core bundle of policy scenarios (numbers 1, 2, and 3 in table 10.2) are in line with the carbon budget used in the 2°C-consistent IPCC mitigation pathways and cooperative scenario number 4, even for some 1.5°C-consistent IPCC mitigation pathways.

TABLE 10.2 Structure of Low-Carbon Transition Scenarios

Scenario	Climate policies	Trade policies	Resulting carbon budget, 2018–50[a]
NDC (reference)	Reference with unconditional NDC pledges[b]	No border carbon taxes	1,362 Gt CO_2
1. COOP	Global cooperative carbon taxes	No border carbon adjustment	862 Gt CO_2
2. UNILAT	Unilateral carbon taxes in CPLs	No border carbon adjustment	
3. UNI-BCAT		Border carbon adjustment taxes levied by CPLs on carbon content of imports from FFDCs	
4. COOP<<2C	High global cooperative carbon taxes	No border carbon adjustment	777 Gt CO_2

Source: World Bank staff calculations.
Note: CO_2 = carbon dioxide; COOP = cooperative carbon tax implemented by all countries, including CPLs and FFDCs; COOP<<2C = a more ambitious cooperative sensitivity scenario; CPLs = climate policy leaders; FFDCs = fossil fuel–dependent countries; Gt = gigaton; NDC = nationally determined contribution; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.
a. Gross cumulative CO_2 emissions during 2018–50.
b. NDC commitments are assumed to continue at the current level of ambition until 2050.

In the cooperative scenarios (COOP), all countries, including FFDCs, implement domestic carbon prices with the same rates (figure 10.5, panel a). FFDCs' cooperation allows most CPLs to apply lower carbon tax rates than in unilateral scenarios (UNILATs). The standard cooperative scenario and both unilateral policy scenarios are calibrated to have the same cumulative CO_2 emissions.

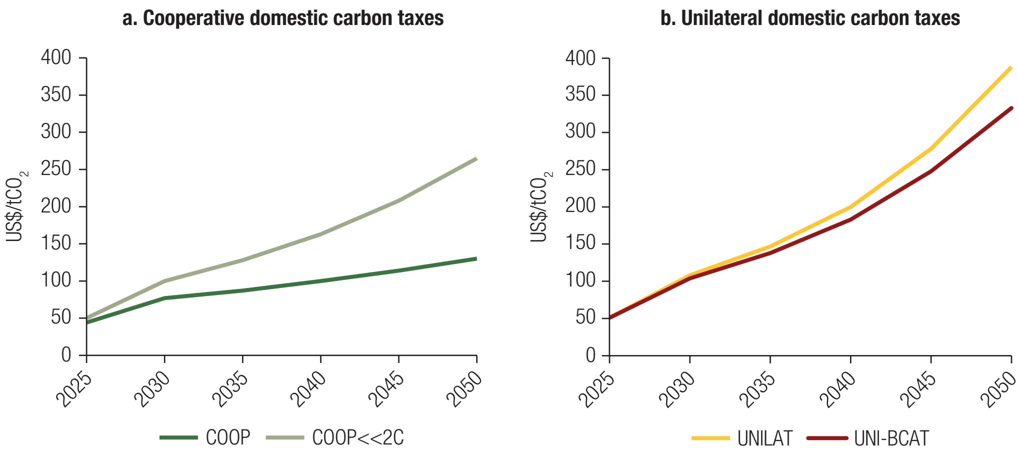
In unilateral policy scenarios, CPLs are assumed to implement unilateral carbon taxes on domestic CO_2 emissions, ramping them up steeply between 2025 and 2030 and at a slightly slower rate from 2030 to 2050. FFDCs are assumed not to increase their domestic carbon prices beyond their near-zero historical trends (figure 10.5, panel b), hence free ride on the ambitious climate action of CPLs.

In one unilateral policy scenario (UNI-BCAT), CPLs apply a BCAT on the carbon content of imports from noncooperating FFDCs. Border carbon taxes applied by CPLs have the same rates as their domestic carbon taxes. Producers try to pass through domestic carbon taxes and border carbon taxes to final consumers subject to competitive market conditions and price elasticities of intermediate and final demand for goods and services downstream in the fossil fuel value chains.

COOP, UNILAT, and UNI-BCAT scenarios are calibrated to result in cumulative gross CO_2 emissions of 862 Gt CO_2 between 2018 and 2050, which is in the range of the mitigation pathways consistent with the 2°C warming goal of the Paris Agreement.

Sensitivity analysis was conducted with a more ambitious cooperative scenario (COOP<<2C). The model was pushed to simulate as high carbon taxes as it was possible for ENVISAGE to find a cooperative equilibrium

FIGURE 10.5 Cooperative and Unilateral Domestic Carbon Taxes, 2025–50



Source: World Bank staff calculations.
Note: COOP = cooperative carbon tax implemented by all countries, including climate policy leaders (CPLs) and fossil fuel–dependent countries; COOP<<2C = a more ambitious cooperative sensitivity scenario; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes; US\$/tCO_2 = US dollars per metric ton of carbon dioxide.

solution. It resulted in cumulative gross CO_2 emissions of 777 Gt CO_2 in the period, consistent with the goal of limiting global warming to well below 2°C (even several IPCC 1.5°C scenarios). In unilateral scenarios, the model could not find equilibrium with higher carbon taxes and correspondingly lower carbon budget consistent with mitigation pathways well below 2°C. This may be the result of a limitation of the model or because the neoclassical economic theory, on which it is based, is not well suited to handle such policy shocks.

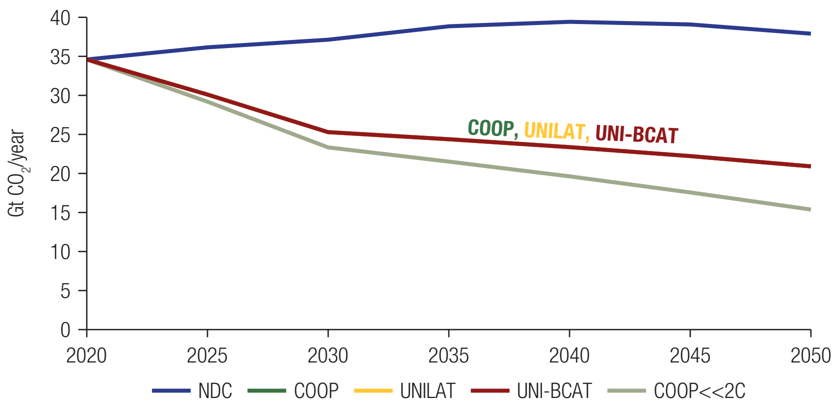
Simulation Results

Gross CO_2 Emissions

In all the climate policy scenarios consistent with limiting global warming to less than 2°C, cooperative or not, annual global gross CO_2 emissions have a similar downward trajectory (figure 10.6). They all reach cumulative gross emissions of 994 Gt of CO_2 between 2014 and 2050 (862 Gt in the 2018–50 period). In the more ambitious cooperative scenario, with higher carbon taxes, emissions drop at a faster rate, reaching a cumulative carbon budget of 909 Gt (777 Gt) of CO_2 in these periods, respectively.

This version of ENVISAGE calculates gross cumulative CO_2 emissions until 2050 and does not include CCS on fuel combustion installations or CDR methods. CDRs typically cover negative emissions from bioenergy with carbon capture and storage; the sequestration potential of

FIGURE 10.6 Profile of Global Gross CO_2 Emissions, 2020–50



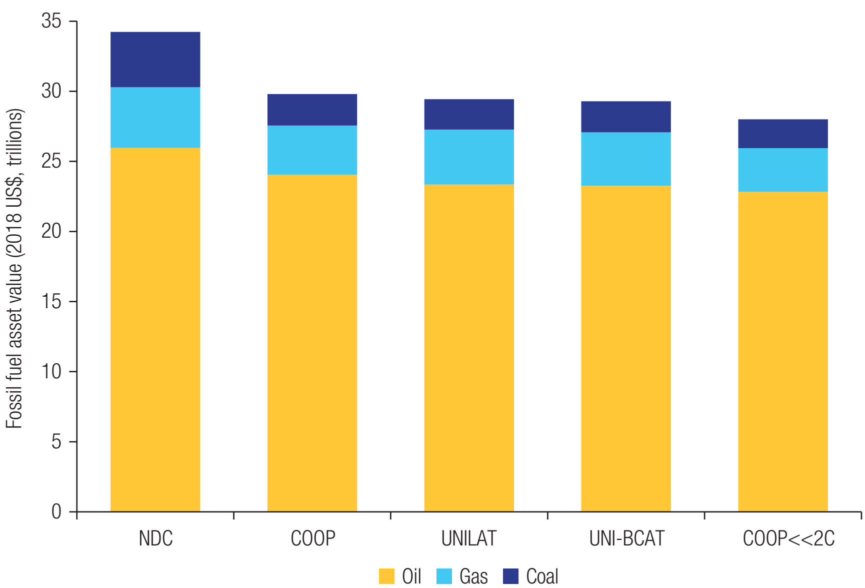
Source: World Bank simulations with ENVISAGE.
Note: COOP = cooperative carbon tax implemented by all countries, including climate policy leaders (CPLs) and fossil fuel–dependent countries; COOP<<2C = a more ambitious cooperative sensitivity scenario; Gt CO_2 = gigatons of carbon dioxide; NDC = nationally determined contribution; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.

agriculture, forestry, and other land use sectors; or direct air capture. The IPCC says that overall CDR deployment over the 21st century is substantial in most of the 1.5°C-consistent mitigation pathways, ranging from 100 Gt CO_2 to more than 1,000 Gt CO_2, not counting CCS potential (Rogelj, Shindell, et al. 2018). Most of this potential is expected to be deployed in the second half of the century. Rogelj, Shindell, et al. (2018) provide a multimodel comparison of climate mitigation policies that are consistent with the 1.5°C goal. In the supplementary materials, they report lower and higher estimates of 2016–50 carbon budgets consistent with different shared socioeconomic pathways (minimum–maximum, all in Gt CO_2): SSP1 (525–1,025), SSP2 (625–850), and SSP5 (875–900). With total gross CO_2 emissions of around 840 Gt (over 2016–50) in the COOP<<2 scenario, this is below the maximum boundary of the 1.5C° target for all shared socioeconomic pathways. The model in this chapter does not have CCS/CDRs, while all the models reported in Rogelj, Shindell, et al. (2018) do have it. So, subtracting another 50–150 Gt CO_2 (a rough estimate that CCS/CDR would contribute by 2050) would bring the CO_2 budgets down to 775 Gt in COOP and 690 Gt in the COOP<<2C scenarios in the 2016–50 period–even closer to the lower, safer boundaries in the IPCC literature on the 1.5C° mitigation target. The same conclusions are derived from comparison with the scenarios in Rogelj et al. (2019) and Huppmann et al. (2019). Uncertainty about climate-forcing potential, feasibility, and costs of CCS and CDRs remains large because they are not yet commercially or even economically proven. Having said that, this study does not pretend to cover all plausible carbon pricing scenarios. A wider set of low-carbon transition scenarios can be found in Mercure et al. (2018), Peszko, van der Mensbrugghe, and Golub (2020), and Van der Ploeg and Rezai (2019). CPLs can apply an even higher level of climate policy ambition than the most ambitious scenarios, for which this model could find an equilibrium solution.

Risk to the Value of Fossil Fuel Assets

A range of low-carbon transition scenarios can reduce the value of fossil fuel assets by between US$4.4 trillion and US$6.2 trillion (in 2018 prices) over 2018–50, compared with what could be expected in the NDC scenario. The total value of all fuel assets does not materially differ between scenarios with the same CO_2 budget, although in the cooperative scenario, the value of oil is slightly greater than in the unilateral policy scenarios (figure 10.7). In the high carbon tax cooperative COOP<<2C scenario, the fossil fuel asset value (US$28 trillion) is US$6.2 trillion lower than the US$34.2 trillion in the NDC scenario. These results suggest that the total global value of fossil fuel assets is more sensitive to the level of ambition of climate policy than to the level of international cooperation in

FIGURE 10.7 Value of Subsoil Fossil Energy Assets, by Fuel, 2018–50



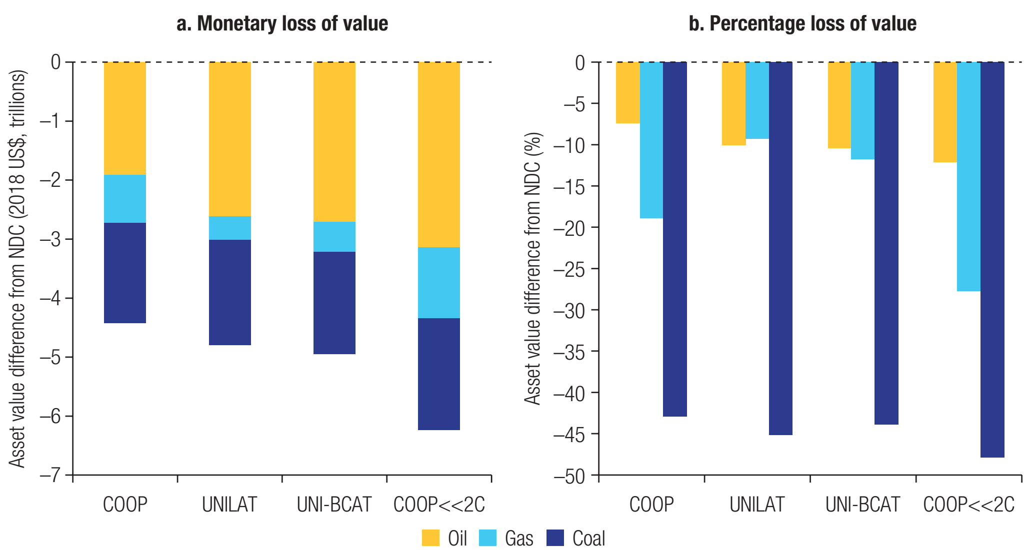
Source: World Bank staff simulations with ENVISAGE.
Note: COOP = cooperative carbon tax implemented by all countries, including climate policy leaders and fossil fuel–dependent countries; COOP<<2C = a more ambitious cooperative sensitivity scenario; NDC = nationally determined contribution; UNI-BCAT = unilateral carbon taxes applied by climate policy leaders with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by climate policy leaders without border carbon adjustment taxes.

implementing this policy. Even in the most stringent climate policy scenario, however, the total fossil fuel wealth is higher than in the conservative estimates consistent with SNA standards based on the extrapolation of the low average price and fixed production level from 2014–18 until 2050 (as in the CWON core accounts).

In dollar terms, oil assets represent the largest value at risk and gas assets the lowest, but in percentage terms, the value of coal is most vulnerable to transition risk, while oil wealth is most resilient. In all scenarios, oil reserves left in the ground because of climate policies represent the largest value of the stranded fossil fuel assets, followed by coal and natural gas—US$3.1 trillion, US$1.9 trillion, and US$1.2 trillion, respectively—in the most ambitious climate policy scenario (figure 10.8, panel a). In percentage terms, across scenarios, coal reserves are valued 43 to 48 percent less than in the NDC scenario (figure 10.8, panel b). This is a big difference compared with natural gas and oil, which in no scenario are valued less than 28 and 13 percent, respectively, below NDC. Most of the coal is used in power generation which, under ambitious climate policies, is easier to replace with alternative inputs than oil in the transport sector and gas in industry, buildings, and transport.

Cooperative policies are better for global oil wealth with the same carbon budget. Lower carbon prices in oil-importing countries translate

FIGURE 10.8 Stranded Fossil Fuel Assets: Loss of Value against NDC, by Fuel, 2018–50



Source: World Bank staff simulations with ENVISAGE.

Note: COOP = cooperative carbon tax implemented by all countries, including climate policy leaders and fossil fuel–dependent countries; COOP<<2C = a more ambitious cooperative sensitivity scenario; NDC = nationally determined contribution; UNI-BCAT = unilateral carbon taxes applied by climate policy leaders with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by climate policy leaders without border carbon adjustment taxes.

into lower fuel prices for consumers than in unilateral action scenarios, and hence slower penetration of electric vehicles in transport and prolonged external oil demand for FFDC producers. Oil importers, including Organisation for Economic Co-operation and Development (OECD) countries, China, and India, maintain the dominant share in the global vehicle fleet toward 2050.

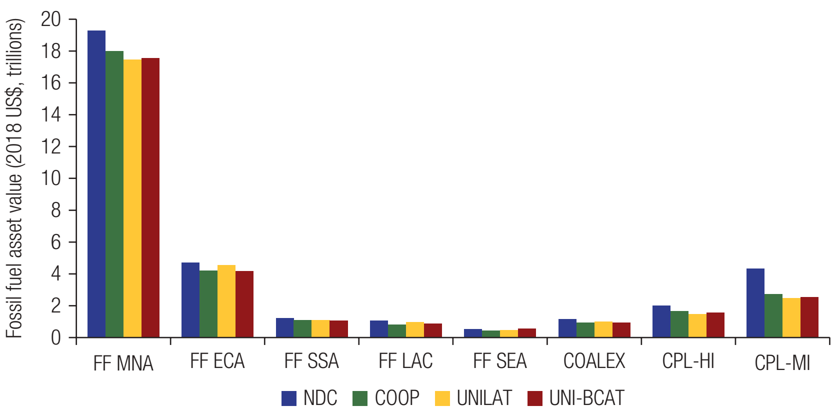
In contrast, natural gas has a higher global value in the noncooperative scenarios. Gas owners seem to benefit from asymmetric climate policies, in which gas exporters in FFDCs free ride on the increased level of climate policy ambition by CPLs and attract emission-intensive industries, even paying the price of BCAT. Coal value suffers similar large losses in all scenarios.

Risk Distribution across Regions

The countries that are the most generously endowed with fossil fuel wealth also face the highest value of fossil fuel assets exposed to transition risk. Three country groups—MNA, ECA, and the middle-income fuel importers (mainly China and India)—account not only for 83 percent of the global fossil fuel wealth in the NDC scenario but also for 77–80 percent of the global loss of fossil fuel wealth in the climate policy scenarios (figure 10.9).

MNA loses the highest dollar value of stranded oil assets but the smallest percentage of its total fossil fuel wealth (figure 10.10).

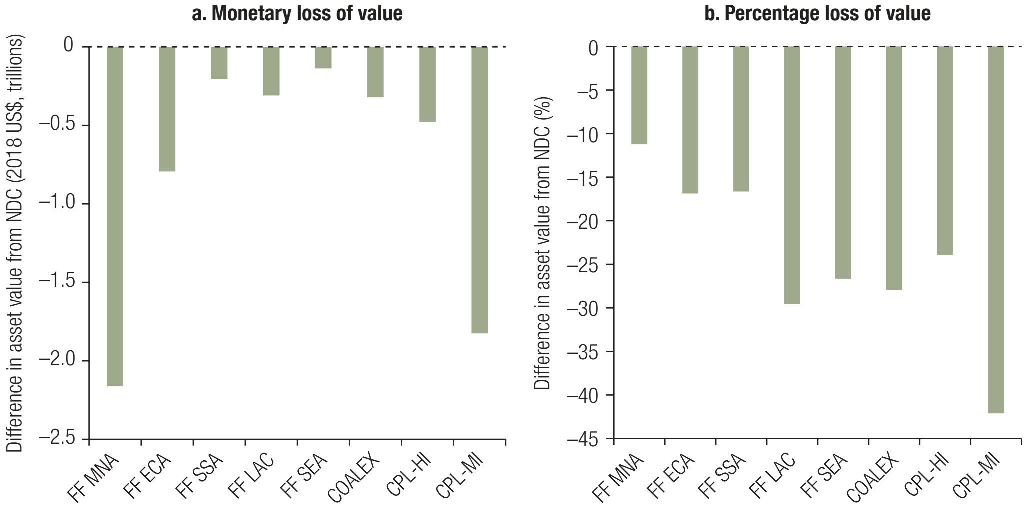
FIGURE 10.9 Value of Subsoil Fossil Fuel Assets, by Scenario and Region, 2018–50



Source: World Bank staff simulations with ENVISAGE.

Note: COALEX = coal exporters; COOP = cooperative carbon tax implemented by all countries, including CPLs and fossil fuel–dependent countries; CPL = climate policy leader; ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); HI = high-income fossil fuel importers; LAC = Latin America and the Caribbean; MI = low- and middle-income fossil fuel importers; MNA = Middle East and North Africa; NDC = nationally determined contribution; SEA = Southeast Asia; SSA = Sub-Saharan Africa; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.

FIGURE 10.10 Risk to Fossil Fuel Wealth in the Most Ambitious (COOP<<2C) Climate Policy Scenario, by Region



Source: World Bank staff simulations with ENVISAGE.

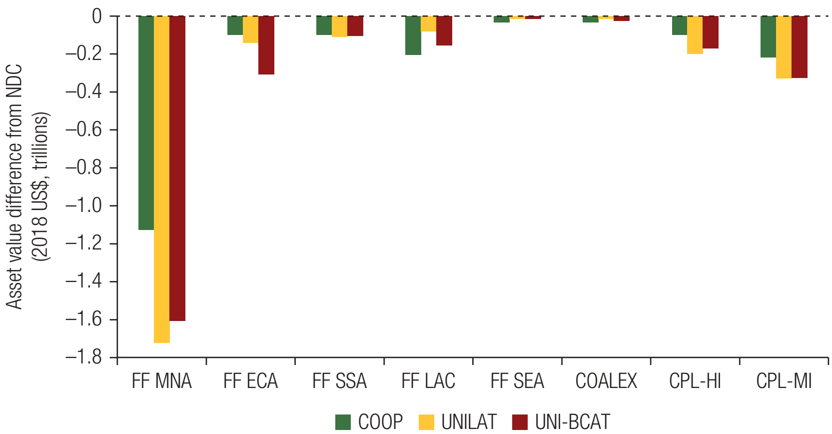
Note: Both panels show the impact only of the cooperative scenario with high carbon taxes. COALEX = coal exporters; COOP = cooperative carbon tax implemented by all countries, including CPLs and fossil fuel–dependent countries; COOP<<2C = a more ambitious cooperative sensitivity scenario; CPL = climate policy leader; ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); HI = high-income fossil fuel importers; LAC = Latin America and the Caribbean; MI = low- and middle-income fossil fuel importers; MNA = Middle East and North Africa; NDC = nationally determined contribution; SEA = Southeast Asia; SSA = Sub-Saharan Africa.

The second-largest foregone value of fossil fuel assets is experienced by the middle-income net fuel importers, especially China and India (US$1.8 trillion, compared with NDC), and it is mainly foregone coal wealth. These countries also lose a higher share of their fossil fuel asset value than any other region (up to 42 percent). ECA countries also have a large value (US$0.8 trillion) of fossil fuel assets at risk of low-carbon transition, but this value is a relatively smaller portion (17 percent) of their total fossil fuel wealth.

Risk Distribution across Regions and Fuels

The value of individual fuels foregone by different regions sheds light on the political economy of international cooperation toward the goals of the Paris Agreement (figure 10.11, figure 10.12, and figure 10.13). Cooperative climate policies benefit oil wealth, especially owners of low-extraction cost reserves. Most large oil producers (MNA, ECA, Sub-Saharan Africa, and both groups of net oil importers) forego less oil wealth in cooperative climate policy scenarios than in unilateral scenarios with the same carbon budget (figure 10.11). For example, compared to the NDC scenario, MNA oil producers extract US$1.1 trillion less of the oil asset value when they implement cooperative carbon prices, and US$1.7 trillion less when they free ride. MNA is

FIGURE 10.11 Potential Loss of Oil Asset Value, by Region

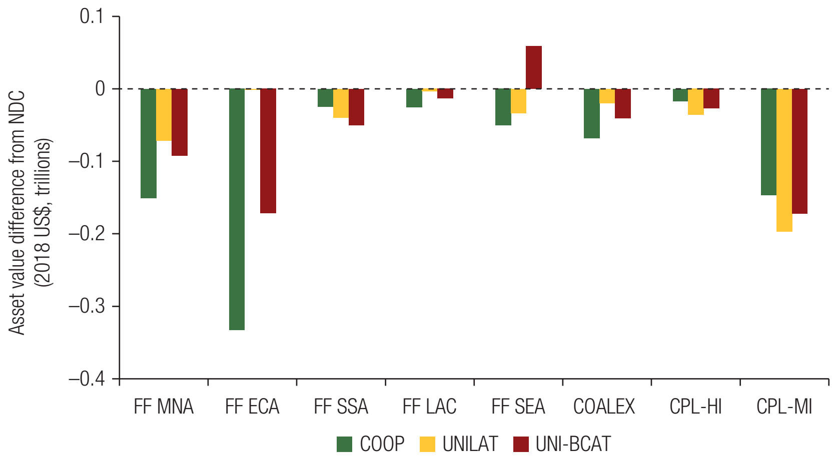


Source: World Bank staff simulations with ENVISAGE.
Note: COALEX = coal exporters; COOP = cooperative carbon tax implemented by all countries, including CPLs and fossil fuel–dependent countries; CPL = climate policy leader; ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); HI = high-income fossil fuel importers; LAC = Latin America and the Caribbean; MI = low- and middle-income fossil fuel importers; MNA = Middle East and North Africa; NDC = nationally determined contribution; SEA = Southeast Asia; SSA = Sub-Saharan Africa; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.

disproportionally well endowed in large conventional oil and gas reserves, with one of the world's lowest extraction costs. The oil exporters in MNA increase their share of global oil asset value from 69 percent in NDC to 71 percent in all the climate policy scenarios, mainly at the expense of the CPLs. The cooperative scenarios allow CPLs (major oil importers and users) to keep their domestic carbon taxes lower, prolonging their transition away from internal combustion engines in transport and hence demand for oil, compared with the unilateral counterfactual. Oil producers in Latin America and the Caribbean seem to be the exception—cooperative scenarios destroy a higher value of their oil wealth than free riding because their extraction costs are high relative to other large producers and they are further from the major growing sources of demand in Asia. They are one of the first producers to be priced out of the declining global oil market, but without carbon pricing they maintain higher domestic demand for oil in transport and the petrochemical industry.

Natural gas owners in FFDCs seem to have opposite incentives to cooperate on climate action than gas owners in importing countries. In virtually all the FFDCs, the value of extracted natural gas is much lower when they cooperate on global climate action than when they free ride (figure 10.12). Contrary to oil, the gas wealth in FFDCs (except exporters in Sub-Saharan Africa) is higher when these countries free ride on

FIGURE 10.12 Potential Loss of Natural Gas Asset Value, by Region



Source: World Bank staff simulations with ENVISAGE.
Note: COALEX = coal exporters; COOP = cooperative carbon tax implemented by all countries, including CPLs and fossil fuel–dependent countries; CPL = climate policy leader; ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); HI = high-income fossil fuel importers; LAC = Latin America and the Caribbean; MI = low- and middle-income fossil fuel importers; MNA = Middle East and North Africa; NDC = nationally determined contribution; SEA = Southeast Asia; SSA = Sub-Saharan Africa; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.

high carbon prices implemented by CPLs. This effect may be counterintuitive but follows from standard macroeconomic transmission mechanisms. The declines of export demand for gas suppress producer prices, lowering the opportunity costs of using gas at home. The value of exporters' currencies also falls, as a result reversing the Dutch disease and boosting the competitiveness of their other export sectors such as the manufacturing industry. In relatively advanced industrialized gas exporters, a large part of manufacturing output can be found downstream in the gas value chain. The foregone gas export revenues are offset by increased revenues from sales to domestic gas-intensive sectors (industry, households, and transport). Gas-fed manufacturing industries in FFDCs increase market share in globally declining brown sectors, especially when they can get away without facing BCAT. Border carbon adjustment taxes implemented by CPLs cause downward revaluation of gas wealth, reducing the benefits of free riding in all FFDC groups, but not enough to encourage gas owners to support cooperative climate policies. The genuine comparative advantage in emission-intensive industries using gas as input causes a leakage of gas-intensive industrial production and greenhouse gas emissions from net importers to net gas exporters even when a level playing field is established by imposing BCATs. The after-BCAT leakage would be "efficient" (Kossoy et al. 2015). Switching from coal to gas in the power sector plays some role only in cooperative scenarios, in which coal is hit even harder, but this advantage of gas is short-lived, because renewables quickly price gas out of the power sector. More discussion on why the wealth of gas and coal producers in FFDCs benefit from unilateral policies can be found in the "Political Economy of Global Cooperation on Climate Change" section later in the chapter.

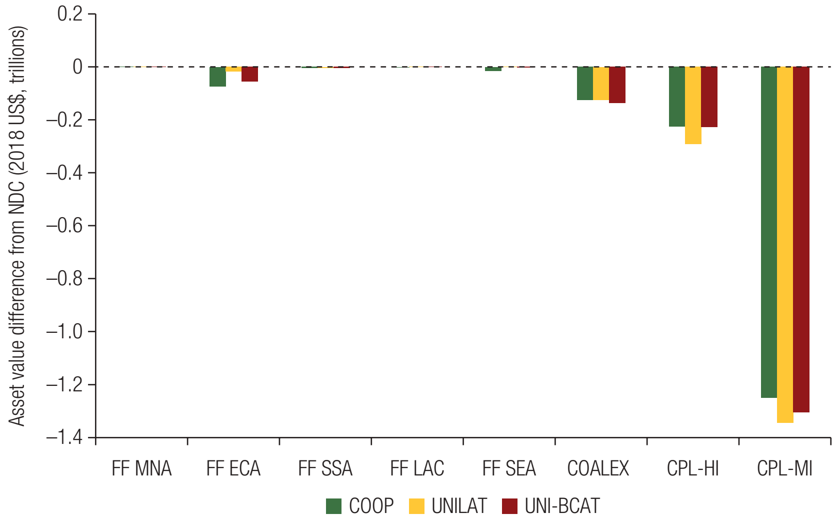
Nowhere are the incentives of gas producers to free ride on low-carbon transition stronger than in ECA and Southeast Asia. The ECA region, including Azerbaijan, Kazakhstan, the Russian Federation, Turkmenistan, and Uzbekistan, faces by far the highest value of natural gas assets at risk in the cooperative scenario, potentially leaving US$330 billion of gas wealth unexploited, compared to the NDC scenario. ECA gas producers also benefit the most from free riding by their countries. The value of ECA's gas wealth in the noncooperative scenario without border carbon adjustments is higher than in the NDC scenario. Even the BCAT does not encourage ECA gas producers to cooperate, since the loss of gas wealth in UNI-BCAT is only US$170 billion against NDC, still only half of the loss in the cooperative scenario. Oil and gas producers in Southeast Asia seem to even benefit from BCAT, which makes their gas wealth higher than in the NDC scenario. This may occur because BCAT accelerates premature retirement of the large coal power plant fleet in the region, increasing demand for gas as a transition fuel for electricity generation. Since the region also has limited variable renewable energy resources, substitution of gas for coal increases not only domestic gas demand but also prices.

Gas exporters in Sub-Saharan Africa are the exception among the FFDCs, as their gas wealth is higher in the cooperative scenarios. Their gas-intensive manufacturing industries are too small to attract any significant production leakage in the noncooperative scenarios. The falling exchange rates do not necessarily reverse the Dutch disease. This occurs only if the fossil fuel–exporting country already has well-developed export sectors such as manufacturing, which SSA countries do not have. Unless these economies diversify away from fuel exports, exchange rate depreciation arising from lower external demand as a result of climate policies implemented by large fuel importers worsens their economic performance. However, the nature of diversification matters. As discussed in Peszko et al. (2020), traditional diversification by branching out to downstream fuel-intensive manufacturing increases the exposure to transition risk.

Unsurprisingly, gas producers in both groups of net fuel importers benefit from cooperative policies, because carbon prices in FFDCs minimize the leakage of gas-intensive industries from CPLs.

Most of the coal wealth foregone in the climate policy scenarios is in the middle-income climate policy leaders (CPL-MI), especially China and India—around US$1.3 trillion or 57 percent less than in the NDC scenario (figure 10.13). The CPLs from the OECD countries and the group of major coal exporters (Australia, Colombia, Indonesia, Mongolia, and South Africa) can also write off significant value of coal assets compared

FIGURE 10.13 Potential Loss of Coal Asset Value, by Region



Source: World Bank staff simulations with ENVISAGE.
Note: COALEX = coal exporters; COOP = cooperative carbon tax implemented by all countries, including CPLs and fossil fuel–dependent countries; CPL = climate policy leader; ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); HI = high-income fossil fuel importers; LAC = Latin America and the Caribbean; MI = low- and middle-income fossil fuel importers; MNA = Middle East and North Africa; NDC = nationally determined contribution; SEA = Southeast Asia; SSA = Sub-Saharan Africa; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.

with NDC policies, US$290 billion and US$140 billion, respectively. The ECA region also leaves some coal value in the ground, but much less than the other three regions. In contrast to the other regions, ECA's coal producers can benefit from the noncooperative behavior of their governments, because of further domestication of coal-intensive industries (power, steel, and cement), already well developed, internationally competitive, and close to the demand for heavy industry intermediate goods in Europe and Asia. BCATs significantly reduce the value of coal wealth in ECA countries because a relatively large share of their industrial exports is directed to Europe and China. However, BCAT does not leave as much of ECA's coal wealth in the ground as cooperative carbon prices do. Coal owners in Australia, Colombia, Indonesia, Mongolia, and South Africa seem to be indifferent to climate and trade policy. They enjoy relatively low coal extraction costs and are close to the premium coal-burning markets in East Asia and South Asia. As expected, all CPL coal producers benefit from global cooperation on climate policies and have self-interest in supporting BCAT against the FFDCs to encourage their cooperative climate policies.

Climate policies also induce shifts in the distribution of coal wealth across countries. China, India, and other middle-income CPLs reduce their share of the global coal asset value from 60 percent in the NDC scenario to 47–49 percent in the climate policy scenarios. Other coal producers, including the group of coal exporters, ECA, and high-income OECD countries, increase their shares of globally declining coal wealth.

Rent Profiles

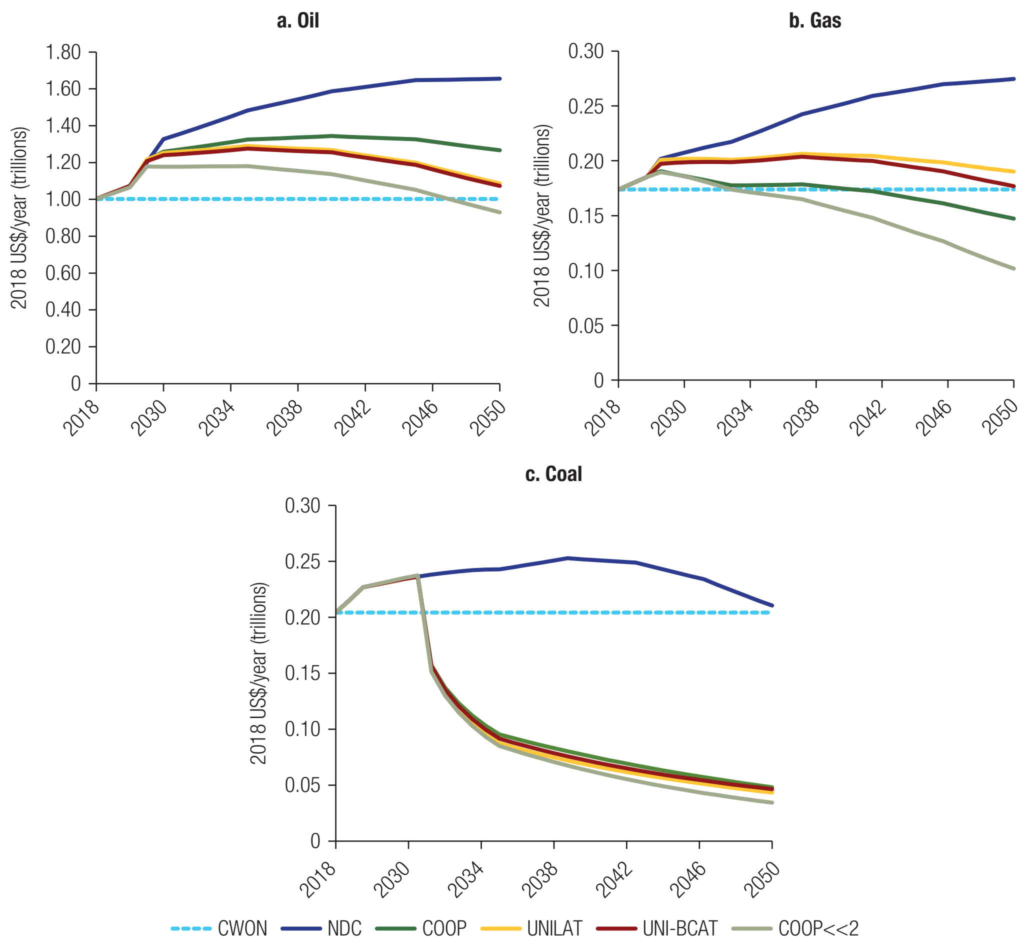
Climate policies can catch many owners of fossil fuel assets by surprise, either because they overlook the need for ambitious climate action or because—despite expecting it—they perceive a "prisoner's dilemma" and delay their own climate action, accumulating exposed assets instead. Therefore, a dynamic and recursive model specification is important to simulate path-dependent adjustments to surprising external changes in policy and the market environment. In ENVISAGE this specification was modified, so that economic agents learn to anticipate at least the near future over time. They make their investment decisions based on past trends until 2030 and with five years' foresight afterward. The specification mimics the myopic expectations of fossil fuel–related interest groups and avoids the pitfalls of static scenarios with long-term perfect foresight that dominate the stranded assets literature.

Owners of extractive companies expect resource rents to increase above average market rates of return, at least in the time frame relevant for shareholders (rarely longer than 10 years). The simulations suggest that NDC commitments do not materially alter these expectations. A steep rise in the ambition of the climate policies, however, abruptly breaks the trends in resource rents, causing potential shockwaves to their valuation (figure 10.14). This rapid adjustment of expectations in response to policy shock applied in 2025 indicates that the impact pathways of the low-carbon transition on fossil fuel asset values can be increasingly erratic.

The simulation results suggest that global oil rents are more resilient to climate policies and decline slower than gas and coal rents (figure 10.14, panel a). Ramping up the ambition level of climate policies in 2025–30 creates an immediate and major deviation from the NDC scenario. This notwithstanding, annual oil rents continue to grow, albeit much more slowly than in the NDC scenario (even slower in asymmetric climate policy scenarios) and begin to decline only after around 2035, by 2050 falling to 24 and 35 percent below rents expected in the NDC scenario in the cooperative and unilateral policy scenarios, respectively. Only in the sensitivity scenario with higher cooperative carbon prices (COOP<<2C) do the oil rents never recover from the 2025–30 policy shock and drop below the 2018 level by 2050 (44 percent below NDC).

Natural gas rents take a deeper dive than oil rents, but contrary to oil rents, natural gas rents lose value faster in the cooperative relative to asymmetric policy scenarios (figure 10.14, panel b). In the NDC scenario, natural gas rents grow after the 2025–30 carbon price shock. In the cooperative and asymmetric policy scenarios, gas rents by 2050 are 46 and 36 percent lower, respectively, than those expected with NDC policies (as much as 63 percent lower in the sensitivity scenario of higher cooperative carbon prices). Only cooperative climate policies suppress gas rents below the 2018 values before 2050. Unilateral climate policies allow for a slower

FIGURE 10.14 Global Rent Profiles for Oil, Natural Gas, and Coal Assets, 2018–50



Source: World Bank staff simulations with ENVISAGE.
Note: COOP = cooperative carbon tax implemented by all countries, including climate policy leaders (CPLs) and fossil fuel–dependent countries; COOP<<2C = a more ambitious cooperative sensitivity scenario; CWON = Changing Wealth of Nations; NDC = nationally determined contribution; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.

decline in gas rents because of migration of some gas-intensive industries (for example, petrochemicals, fertilizers, and power) from CPLs to FFDCs, where they survive longer as the former implement steep carbon taxes alone. Even border carbon adjustments do not destroy the output of gas-intensive manufacturing in FFDCs. Cooperative climate policies reduce gas production and rents faster because they prevent emissions leakage, eliminating "pollution havens" for gas users.

Coal rents are the most vulnerable to climate policies, and rent destruction is similar in all climate policy scenarios (figure 10.14, panel c).

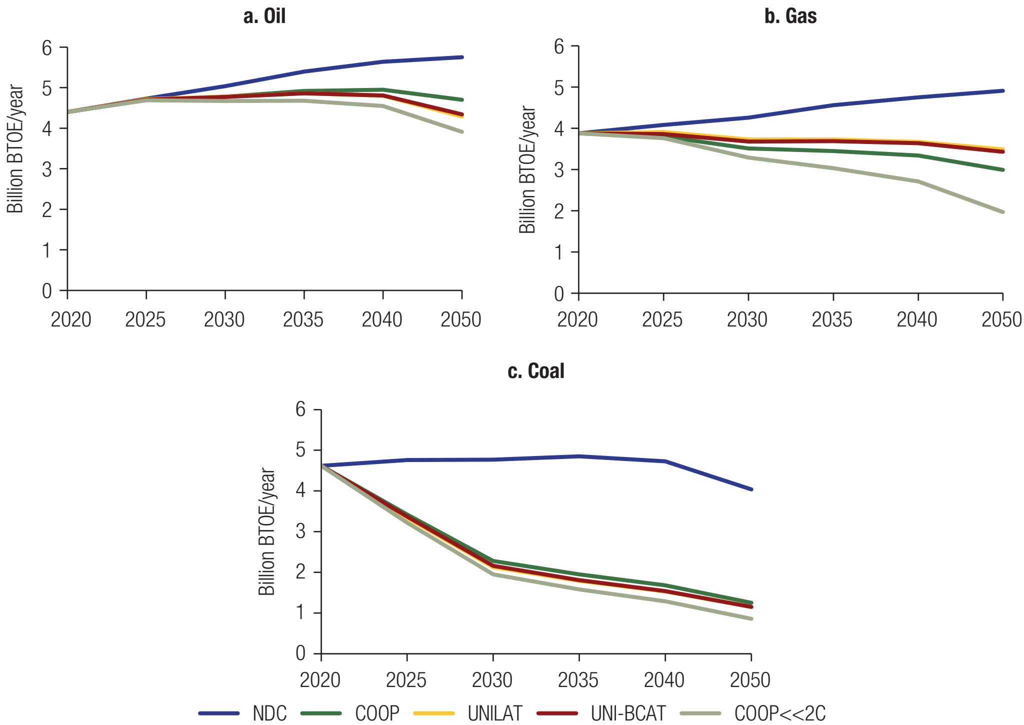
Climate policies assumed to be implemented in 2025 trigger an immediate freefall of global coal rents against the NDC expectations and even below the level in 2018. Within five years of implementation of carbon taxes, annual coal rents drop by 62 percent in real terms in the model, indicating a potentially dramatic impact on the coal industry in the real markets that do not have automatic equilibrium stabilizers as CGE models. By 2050, the annual coal rents collected by the mining countries is just 20 percent of what would have been collected in the NDC scenario and in 2018. To put it into perspective, in 2013–15 annual coal rents dropped by 40 percent globally, as an aftermath of the oil price drop, accompanied by climate and clean energy support policies in the European Union and North America (CWON core accounts). This caused a shockwave of bankruptcies of coal companies and accelerated mine closures in western countries, although coal rents fully rebounded by 2018. The deeper dive of coal rents simulated here, with no hope of rebound, could lead to a much more dramatic shock to the coal mining industry across the world, this time also in Asia and other coal-intensive developing countries.

Production Volumes of Fossil Fuels

The production volumes of fossil fuels are more sensitive to climate policy scenarios than their values are. Physical production volumes of oil and gas fall slightly faster than their rent profiles. Coal production falls slower initially and faster later in the modeling period (figure 10.15). The wedge between the production and rent profiles is attributed to resource prices, which are endogenously calculated by the model to clear the markets. Increasing prices of oil and gas partly offset the impact of the production losses on resource owners. This illustrates a significant difference between the perceptions of environmentalists and resource owners, which often creates avoidable tensions, counterproductive to cooperative climate action. Environmentalists are mainly concerned about volumes, because they determine climate impact, but climate advocacy narratives often attack the profits and rents of fossil fuel producers. Decoupling volumes from rents in the public dialogue could create a much-needed safe space for less confrontational dialogue about low-carbon transition. The resource-rich nations would find it easier to engage in the dialogue on climate policies if they could expect that their rents would be falling slower than their production volumes.

The production profiles of fossil fuels calculated endogenously by ENVISAGE are broadly aligned with the production trajectories taken as exogenous assumed constraints consistent with the 2°C scenarios in the integrated assessment models. There are significant differences across fuels, however. Comparison of figure 10.15 with figure 10.2 suggests that the production of coal and gas in this study is close to the 1.5°C scenarios in SEI et al. (2020), especially for the most comparable COOP<<2C scenario, but production of oil is higher than in most of the 2°C scenarios reported by SEI et al. The model finds more substitution opportunities for coal and gas in power generation and industrial uses and less for oil in transport. Researchers are encouraged to stress test these results with different models.

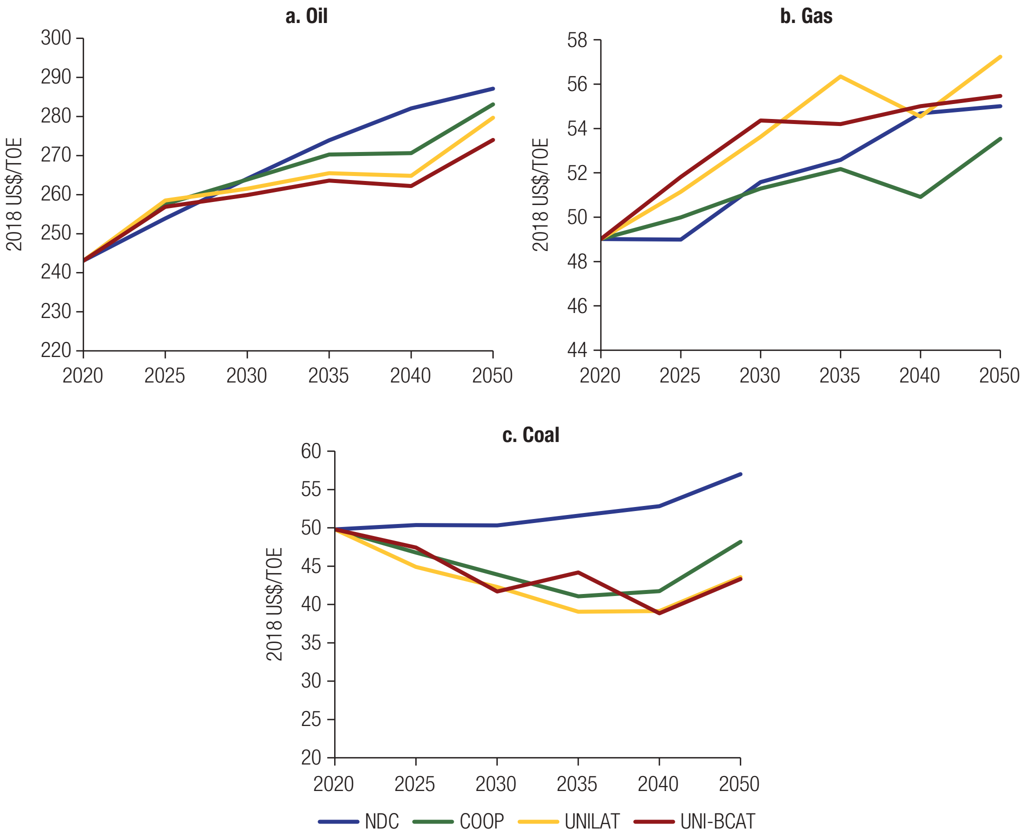
FIGURE 10.15 Production Volumes of Oil, Natural Gas, and Coal, 2020–50



Source: World Bank staff simulations with ENVISAGE.
Note: BTOE = billion tons of oil equivalent; COOP = cooperative carbon tax implemented by all countries, including climate policy leaders (CPLs) and fossil fuel–dependent countries; COOP<<2C = cooperative scenario with high carbon taxes; NDC = nationally determined contribution; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.

This study suggests that oil- and gas-rich countries that survive the low-carbon transition can enjoy higher rents per unit of fuels extracted than current producers. The unit rents for the remaining oil and gas producers roughly follow the increasing NDC trends from 2018 onward, although with greater volatility. This means that resource prices increase slightly faster than extraction costs. Production volumes and unit rents for oil producers are higher in the cooperative scenarios than in unilateral policy scenarios with the same carbon budget (figure 10.16). BCATs have negligible impact on global oil production volumes but reduce producers' rents. This finding mitigates the concerns represented by the green paradox hypothesis, which suggests that expected low-carbon transition fossil will prompt fuel producers to accelerate current production and emissions. The hypothesis argues that producers who expect that low future demand will depress future prices will rationally try to extract as many resource rents as quickly as possible and dump extra fuels on the market. According to green paradox proponents, ambitious long-term NDC targets would

FIGURE 10.16 Profile of Average Unit Rents for Oil, Natural Gas, and Coal, 2020–50



Source: World Bank staff simulations with ENVISAGE.
Note: COOP = cooperative carbon tax implemented by all countries, including climate policy leaders (CPLs) and fossil fuel–dependent countries; NDC = nationally determined contribution; TOE = tons of oil equivalent; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.

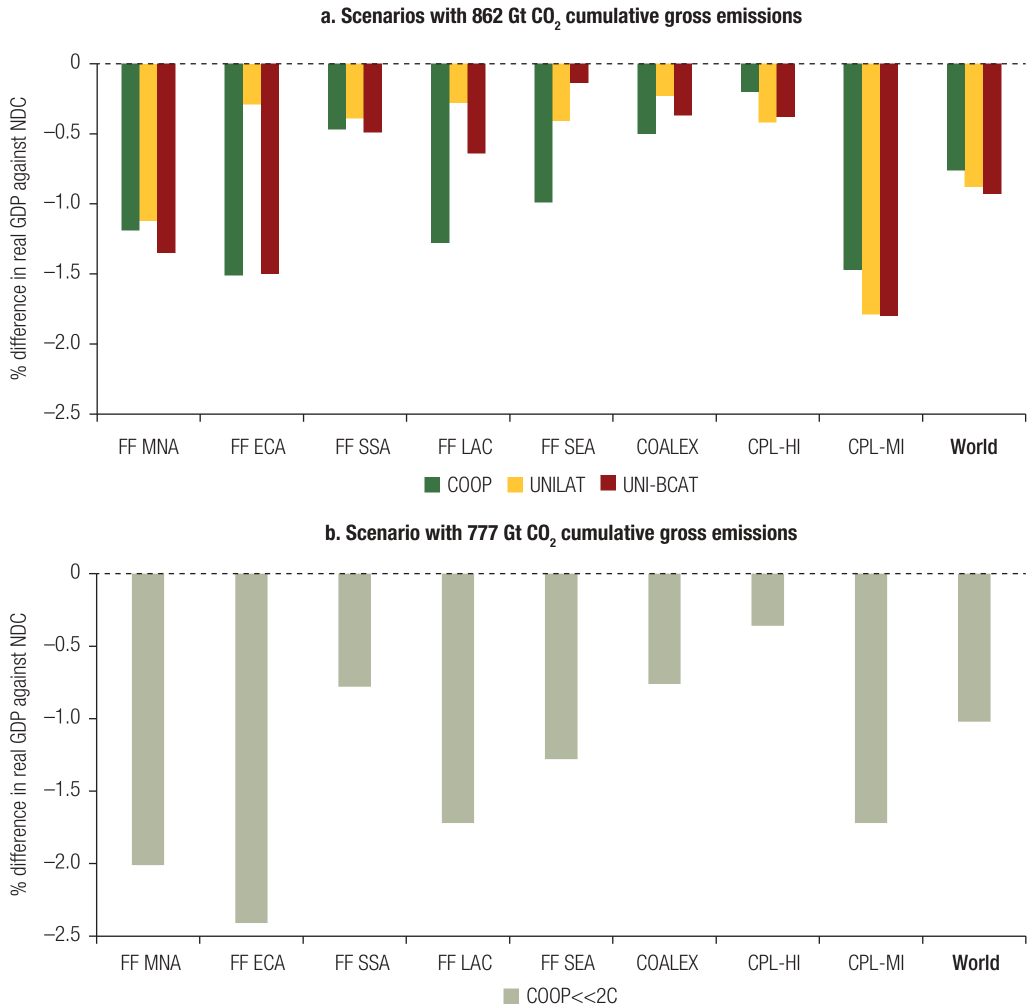
create incentives opposite to those intended (Sinn 2008). These simulations suggest that it is not realistic to expect that fuel demand and prices will smoothly decrease together and that at least some producers can capture significant resource rents in the future and hence can delay extraction. It also confirms an earlier hypothesis that some fossil fuel producers can successfully pursue risky *leadership strategies* (opposite to divestment) and try to increase their market share and market power in the globally declining fuel-intensive sectors through mergers and acquisitions (Peszko et al. 2020).

For the remaining coal producers, the unit rent outlook looks grim. In all the climate policy scenarios, even the most competitive coal producers find themselves with not only the total rents but also unit rents falling well below the NDC scenario and even below 2018 levels.

Gross Domestic Product

Figure 10.17 confirms what can already be observed: the low-carbon transition—especially a cooperative one—is least disruptive to high-income OECD net fuel importers (CPL-HI), which therefore have the strongest incentives to be the global CPLs. The low-carbon transition is more

FIGURE 10.17 Difference in Real GDP against the NDC Scenario



Source: World Bank staff simulations with ENVISAGE.

Note: COALEX = coal exporters; COOP = cooperative carbon tax implemented by all countries, including CPLs and fossil fuel–dependent countries; COOP<<2C = cooperative scenario with high carbon taxes; CPL = climate policy leader; ECA = Europe and Central Asia; FF = fossil fuel(–dependent countries); GDP = gross domestic product; Gt CO_2 = gigatons of carbon dioxide; HI = high-income climate policy leaders; LAC = Latin America and the Caribbean; MI = low- and middle-income fossil fuel importers; MNA = Middle East and North Africa; NDC = nationally determined contribution; SEA = Southeast Asia; SSA = Sub-Saharan Africa; UNI-BCAT = unilateral carbon taxes applied by CPLs with border carbon adjustment taxes; UNILAT = unilateral carbon taxes applied by CPLs without border carbon adjustment taxes.

challenging for other countries, including coal-intensive fuel importers (CPL-MI), such as Cambodia, China, India, Morocco, Serbia, Turkey, and Ukraine, to say nothing of FFDCs, because of the higher carbon intensity of their economies. Among the FFDCs, the least negative impact on total economic output can be found among coal exporters. Although coal assets are the hardest hit by low-carbon transition, coal export revenues are a small share of total exports and GDP, even among the largest exporters.

The substantial difference between the net fuel importers (CPL-MI) and the FFDCs is that the former benefit from cooperative climate policies, while the latter benefit from industrial and emissions leakage when free riding on climate policies of CPLs (figure 10.17). This identifies probably the most important challenge to establishing a stable cooperation to implement the goals of the Paris Agreement. BCAT appears to be an important incentive for FFDCs to engage in cooperative climate policy, but unsurprisingly it is not necessarily a very attractive policy for CPL growth, unless it induces cooperative behavior by FFDCs.[6] The retaliation of FFDCs is not part of the simulated scenarios. It would make BCAT even less attractive to all countries. Therefore, the rational CPLs coalition would rather use BCAT as a credible threat rather than a long-term actual trade policy

Comparison with Other Estimates of Stranded Assets

Approaches to measuring stranded assets vary considerably in the literature. They are difficult to compare across studies, reflecting the early stage of the field. Comparison between studies is complicated by the fact that different authors consider different metrics (what is stranded, and compared to what counterfactual), often loosely using the term *assets* as a metaphor rather than a balance sheet concept consistent with the SNA definition of assets. They compare "stranded" value to the different categories of reserves and use different scenarios, time horizons, discount rates, price levels, and so forth. Many studies measure unburnable reserves left in the ground in physical (volume) rather than in value terms (IEA 2012; McGlade and Ekins 2015). Some quantitative studies focus on produced assets, such as thermal power plants, rather than subsoil assets (Baldwin, Cai, and Kuralbayeva 2018; Bertram et al. 2015; Carbon Tracker Initiative 2013; Coulomb, Lecuyer, and Vogt-Schilb 2019; Guivarch and Hallegatte 2011; Koch and Bassen 2013; Löffler et al. 2019; Pfeiffer et al. 2018; Pfeiffer et al. 2016; and Rozenberg, Vogt-Schilb, and Hallegatte 2020). Several authors, financial institutions, and rating agencies employ the value-at-risk approach to calculate risk to financial assets that are invested in fossil fuel–dependent produced capital rather than measuring the risk to the value of subsoil assets themselves (for example, Dietz et al. 2016; Spedding, Mehta, and Robins 2013). The models and calculation methods chosen by researchers often involve inherent biases, which are rarely discussed explicitly. Only very few recent peer reviewed studies compare their results with other studies and explain the sources of differences (see Mercure et al. 2018; Peszko, van der Mensbrugghe, and Golub 2020; and Van der Ploeg and Rezai 2019. Table 10.3 compares the most relevant global studies.

TABLE 10.3 Comparative Assessment of Studies of Stranded Assets

Study	Metrics	Volume or value	Baseline reserves	Scenarios	Model or calculation method	Geographic breakdown	Discount rate	Price level
This study	*Fossil fuel asset value:* NPV of oil, gas, and coal resource rents against reference NDC scenario	*Value:* US$4.4 trillion to US$6.2 trillion globally (up to US$3.1 trillion for oil, US$1.9 trillion for coal, and US$1.2 trillion for gas), 2020–50	*Class A:* Producing under market conditions simulated by model	BAU (with NDC) plus cooperative and noncooperative carbon taxes with and without border carbon adjustment tax	Economywide global CGE (ENVISAGE) with endogenous resource exploration and extraction module	16 country groups: fuel exporters and importers	4%	2018
Carbon Tracker 2011	Unburnable reserves	*Volume:* 80% of proven reserves technically unburnable	All the proven reserves owned by private and public companies and governments	BAU, all proven reserves burned versus reserves that could be burned with 565 Gt CO_2 carbon budget	Bottom-up calculations	Global	n.a.	n.a.
IEA 2013	Reserves that cannot be used and foregone revenues	*Volume/value:* Oil and gas gross revenue 15% and coal 32% lower than in NPS (but three times higher than in previous period); less than 5% and 6% of new proven oil and gas reserves, respectively, to be developed	*Class A:* Producing under market conditions assumed by researchers	IEA NPS versus 450 ppm (2°C) scenarios (884 Gt CO_2 from the energy sector in 2012–50)	Bottom-up calculations supported by WEO model (partial equilibrium energy model)	Multiple countries (focus on owners of coal reserves)	n.a.	n.a.
Lewis et al. 2014	*Gross revenues:* Foregone by fossil fuel industry compared with IEA CPS scenarios	*Value:* US$28 trillion: US$19.3 trillion, US$4 trillion, and US$4.9 trillion, respectively, for oil, gas, and coal by 2035	n.a.	IEA scenarios from 2013 WEO (CPS, NPS, 450 ppm scenario)	Calculation based on IEA projections of fuel prices and demand by scenario	Global fossil fuel industry	n.a.	2012
Nelson et al. 2014	*Profits of extractive sectors:* Resource rents and returns on extractive capital	*Value:* US$15 trillion by 2035, of which oil, US$11.2 trillion; gas, US$1.7 trillion; and coal, US$2.2 trillion, 2015–35 (net of transfers)	*Class A:* Producing under IEA BAU scenario	Fuel demand under IEA 2C scenario	Supply (cost) curves for coal, oil, gas, and electricity	Multiple country groups	8%	2015
McGlade and Ekins 2015	Unused fossil fuels	*Volume:* 33% of oil reserves, 50% of gas reserves, and over 80% of current coal reserves should remain unused from 2010 to 2050 in 2C target	*Class A and partly B:* Proven and probable reserves	Technology-driven sensitivity scenarios	Linear optimization IAM: TIAM-UCL13 with supply cost curves for oil, gas, and coal	Multiple country groups	n.a.	n.a.

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TABLE 10.3 Comparative Assessment of Studies of Stranded Assets *(continued)*

Study	Metrics	Volume or value	Baseline reserves	Scenarios	Model or calculation method	Geographic breakdown	Discount rate	Price level
Carbon Tracker 2C of Separation 2017 with 2018 update	Unneeded upstream oil and gas capex to 2018–25	*Value:* US$4 trillion (2017), $2.3 trillion for 2C, and US$3.3 trillion for 1.75C	Potential supply from Rystad under EIA NPS	Company-by-company calculations	Carbon supply cost curves	Multiple companies	n.a.	2018
Carbon Tracker Mind the Gap 2018	Capex in upstream oil, gas, and thermal coal projects over 2018–25 above what is needed in EIA NPS	*Value:* US$1.6 trillion capex at risk in 1.75C scenario (33% of NPS); in 2C scenario, US$0.9 trillion (18% of NPS)	Fuel demand under the EIA NPS	EIA NPS (no policy scenario), and IEA B2DS (1.75C) and EIA SDS (2C) scenarios	Carbon supply cost curves	Multiple countries	n.a.	2018
Mercure et al. 2018	Loss of income on sales of fossil fuels	*Value:* US$1 trillion to US$4 trillion cumulative difference globally in the value of oil, gas, and coal to 2035	*Class A:* Produced in BAU and policy scenarios	Two BAUs: fuel use from IEA new policies and from technology diffusion trajectory; and policy scenarios based on combinations of carbon prices and trading strategies of producers	E3ME-FTT-GENIE dynamic simulation models (with macroeconometric core with imperfect foresight)	Multiple country groups (fuel exporters and importers)	10%	2016
Van der Ploeg and Rezai 2019	*Multiple:* market valuations, investments, and carbon resources and their scarcity rents belonging or accruing to international oil and gas companies	*Value:* Range of results stated as in line with US$2.3 trillion of unneeded capex from Carbon Tracker 2017.	*Class A and partly B:* Assumed produced under BAU (from proven reserves and new discoveries)	Unexpected stepping-up and abandoning announced climate policy scenario (carbon taxes versus RES subsidies)	Model of endogenous exploration in the global oil and gas industry	Global oil and gas industry	n.a.	n.a.
Carbon Tracker 2020	NPV of resource rents	*Value:* US$100 trillion gap between the assumed desired fossil fuel wealth of the petrostates and the assumed aspirations of the Paris Agreement	n.a.	Alternative combinations of two variables: (1) FF rents as a share of global GDP and (2) the discount rate	Back-of-the-envelope calculations based on selected studies	Global	Variable	2019

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TABLE 10.3 Comparative Assessment of Studies of Stranded Assets *(continued)*

Study	Metrics	Volume or value	Baseline reserves	Scenarios	Model or calculation method	Geographic breakdown	Discount rate	Price level
Peszko, van der Mensbrugghe, and Golub 2020	*Fossil fuel asset value:* NPV of oil, gas, and coal resource rents plus produced assets (value added attributed to capital across sectors against BAU in 2021–50)	*Value:* Asset value against BAU: coal minus US$0.5 trillion to US$1.2 trillion; gas from plus US$300 billion to minus US$2.8 trillion; oil minus US$5 trillion to US$17 trillion; produced assets shift values	*Class A:* Producing under market conditions simulated by model	BAU and combination of diversification and cooperation scenarios with and without border carbon adjustment taxes	Economywide global CGE (ENVISAGE) with endogenous resource extraction module (endogenous prices, demand, and supply cost curves)	15 country groups: fuel exporters and importers	6%	2013
Guivarch and Hallegatte 2011; Carbon Tracker Initiative 2013; Koch and Bassen 2013; Bertram et al. 2015; Pfeiffer et al. 2016; Pfeiffer et al. 2018; Baldwin, Cai, and Kuralbayeva 2018; Coulomb, Lecuyer, and Vogt-Schilb 2019; Rozenberg, Vogt-Schilb, and Hallegatte (2020; Löffler et al. 2019	Produced assets, no fossil fuel assets	Vary	n.a.	Vary	Vary	Vary	Vary	Vary

Source: World Bank.

Note: BAU = business as usual; capex = capital expenditure; CGE = computable general equilibrium; CO_2 = carbon dioxide; CPS = current policy scenario; EIA = US Energy Information Administration; FF = fossil fuel; GDP = gross domestic product; Gt = gigaton; IAM = integrated assessment model; IEA = International Energy Agency; n.a. = not applicable; NDC = nationally determined contribution; NPS = new policy scenario; NPV = net present value; ppm = parts per million; RES = renewable energy sources; WEO = World Energy Outlook.

A problem with the physical and monetary estimates is that the authors use different concepts of reserves, some of them not being economic assets. In other words, the authors often count those reserves as stranded that would have zero balance sheet value even in the baseline without low-carbon transition. This confusion was introduced with the first Carbon Tracker report (2011), which popularized the concept of stranded assets. In the SNA/SEEA, standard proven reserves include three distinct categories, class A, B, and C deposits. Only category A deposits (defined as producing or commercially recoverable under the current market conditions) are considered assets. IEA (2013, 2015) stressed that most known fossil fuel reserves (for example, 60 percent of known coal reserves) would stay in the ground even in the business-as-usual scenario. McGlade and Ekins (2015) define business-as-usual reserves more narrowly, as those reserves that are recoverable under current economic conditions and have a specific probability of being produced. These include class A and part of class B deposits. This is closer to but still broader than the definition of economic assets in the SNA/SEEA/CWON methodology (that is, class A deposits). Such choices may exaggerate the volume and/or value of stranded assets because some class B and C deposits would likely be left in the ground even without low-carbon transition (IEA 2018) and would never enter the balance sheets of the extractive companies or governments. This analysis follows those few forward-looking models (such as Mercure et al. 2018; Peszko, van der Mensbrugghe, and Golub 2020; and Van der Ploeg and Rezai 2019) that allow only some known reserves to be commercially recoverable and producing (hence becoming SNA assets) under the market conditions simulated endogenously in the business-as-usual scenario. Policy scenarios alter these market conditions; hence, they cause shifts in asset values by changing the production volumes, time profiles, and prices of fossil fuels. Only the difference in the present values of such assets between business-as-usual and policy scenarios is a measure of "stranded assets."

The stranded assets literature rarely measures economic assets as defined in the SNA/SEEA. The gray literature, such as the Carbon Tracker, usually measures financial indicators that are relevant to the listed international extractive companies rather than the rental value of subsoil assets. For example, the Carbon Tracker (2015) estimates that fossil fuel firms could risk around US$2.2 trillion in capex on projects that could be "uneconomic" with a 2°C carbon budget constraint. Another Carbon Tracker study (2017, with 2018 update) uses bottom-up extractive industry supply cost curves to estimate that one-third of the capex from new oil development projects approved by the major listed and state-owned oil companies is "unneeded" in a 2°C scenario (25 percent from new gas projects). The capex of committed fossil fuel development projects or production volume is a different economic category than the asset value in the SNA/SEEA (that is, the discounted value of resource rents). On the one hand, the capex of committed fossil fuel development projects is a conservative estimate of the subsoil asset value, since rational economic agents should expect the value of assets created by a project to be larger than the initial capital investment. On the other hand, the capex exaggerates the value of foregone returns to owners, since many projects that are "unneeded" in the long term will generate net returns in the short term, until some external market or regulatory event ceases their operation. A portion of the initial capex will be recovered before the remaining asset value becomes stranded. It also conflates the value of subsoil assets with the value of produced capital involved in their extraction. On the other side of the spectrum, Lewis et al. (2014) use EIA projections of demand for and prices of fossil fuels to calculate the gross revenue (not of rents or assets) of the fossil fuel companies under alternative EIA scenarios.

Nelson et al. (2014) are more closely aligned with the SNA/SEEA definition of assets than most stranded asset studies available so far. They explore the impact of low-carbon transition on the value of investor portfolios with the supply (cost) curves for coal, oil, gas, and electricity and exogenous assumptions of demand. Like many other later studies, however, the rental value of subsoil assets—oil, gas, and coal—is merged with returns to and depreciation of produced capital in extractive industries. This rich and, in many respects, pioneering analysis provides several important policy-relevant insights, one of them being that not all value at risk would be lost in the low-carbon transition—a portion would be transferred from one economic actor to another, or from one country to another, and would find other sometimes less, sometimes more productive economic uses. The authors estimate that governments would bear close to 80 percent of the US$25 trillion value difference for producers. The study also emphasizes the role of transfers within countries (taxes and subsidies) that should be excluded from asset valuation by the SNA/SEEA/CWON standards. After correcting for transfers, the total value at risk falls from US$25 trillion to US$15 trillion by 2035, of which US$11.2 trillion accounts for oil, US$1.7 trillion for gas, and US$2.2 trillion for coal (including resource rents and returns on extractive capital). After correcting for produced capital, time periods, and discount rates, the value given to stranded fuel reserves is comparable to this study's.

Another common problem in the stranded assets literature is that, until recently, almost all studies have simulated impacts of emission pathways rather than policy pathways. Authors stress tested the fossil fuel sectors with exogenous emission caps applied and "enforced" by a modeler rather than shocking them with policy instruments that can be implemented by legislators. Stranded assets are created by reverse engineering of how much fossil fuels can be burned under the binding carbon budget imposed by *deus ex machina* on the energy sector models. This approach makes it difficult to address policy-relevant questions about stranded assets, such as what the key transmission mechanisms of transition risk are, and how to most effectively and efficiently manage asset portfolios to mitigate this risk. This study belongs to the emerging modeling literature that shows that the risk of stranded assets varies by country and fuel and depends significantly on policy instruments and strategies applied by actors of the global low-carbon transition.

Recent studies increasingly use macroeconomic models instead of simple energy models, in which extractive sectors do not interact with the rest of the economy. Mercure et al. (2018) applied a suite of

E3ME-FTT-GENIE dynamic simulation models (including macroeconometric models) relying on empirical data on socioeconomic and technology diffusion trajectories to capture the impact of imperfect foresight by economic agents and alternative strategies of fossil fuel producers. They compare five scenarios built around different expectations of the future demand for fossil fuels, different technology diffusion trajectories, energy and carbon prices, and trading strategies of major producers. They come up with US$1 trillion to US$4 trillion in stranded oil, gas, and coal assets to 2035 as the differences between the baseline scenario and alternative low-carbon transition scenarios. The authors find significant differences between the winners (net importers such as China and the European Union) and the losers (Canada, the Russian Federation, and the United States). The analysis of Mercure et al. (2018) is the closest to this study in terms of metrics, approach, and rigor. The results are in a similar range when corrected for different discount rates, price levels, and time periods, despite using two different macroeconomic cores of the modeling suites, the neo-Keynesian macroeconometric model by Mercure et al. (2018) and the CGE model based on neoclassical economic theory used here.

In another study, Jin and Zhang (2019) show that under some conditions, environmental regulations, by directing investment toward clean capital, do not have to lead to any significant value loss resulting from stranded fossil fuel assets. Van der Ploeg and Rezai (2019) conduct another policy-driven simulation using a model of the global oil and gas extractive industry (without a macroeconomic model). They find that as soon as climate policy is unexpectedly stepped up, exploration capital and fossil reserves suffer a sudden loss in value. The opposite happens when previously announced climate policy is abruptly abandoned. The value of stranded assets is also higher with carbon taxes than with renewable subsidies.

Peszko, van der Mensbrugghe, and Golub (2020) apply an earlier version of the models used in this study to run a wider range of scenarios. They find that fossil fuel exporters can protect the value of their fossil fuel assets by free riding and subsidizing domestic fuel-intensive industries, as this accelerates industrial and emissions leakage (traditional, *emission-intensive diversification* of fuel exporters). This comes at a price, however, of lower long-term consumption and growth and higher exposure to external transition shocks. A flat import fee imposed by fuel importers against nonparticipating FFDCs, as proposed by Nordhaus (2015), represents the worst-case scenario for fuel asset owners in exporting countries. As shown by Peszko, van der Mensbrugghe, and Golub (2020), its credible threat should encourage FFDCs to pursue *asset diversification* beyond fossil fuel value chains and cooperative carbon policies. Both coping strategies would benefit their societies at large but harm the extractive fuel wealth. That study also illustrated that values and composition of nations' wealth will depend on how low-carbon transition unfolds and how countries choose to diversify. Asset diversification would help FFDCs accumulate capital that is more productive and resilient in a decarbonizing world and discover new sources of global comparative advantage outside of the comfort zone of the fossil fuel value chains.

Political Economy of Global Cooperation on Climate Change

From the policy perspective, the question of who loses the most value in what fuel and under what scenario matters much more than any global value of stranded assets. Two country groups stand out with the highest fossil fuel assets value at risk in dollar terms (figure 10.9). The first is MNA, which is heavily dependent on fossil fuel wealth for growth and export revenue. The most exposed fuel in MNA is oil, which is also the most valuable fuel per unit of energy and the most tradable. The second group consists of middle-income fuel importers including China and India. These countries have a large value of coal reserves exposed to low-carbon transition risk, although their growth and export revenues are not dependent on coal (figure 10.4). Potentially stranded coal assets are not a source of systemic macrofiscal risk, although they pose a challenge for low-carbon transition in the electricity sector and social and political risk because of potentially *stranded labor* in coal mining. These two most exposed regions differ in many respects but have one surprising common interest—they both benefit from cooperative low-carbon transition. MNA benefits because lower CPL carbon taxes in the cooperative scenarios prolong the transition away from oil in transport in CPLs, which are the major oil importers. China and India also benefit from cooperation because lower domestic carbon taxes in the cooperative scenarios prevent industrial leakage to FFDCs and delay early retirement of some of the most efficient coal power plants. None of these increase global CO_2 emissions. Total emission trajectories are the same as in the unilateral policy scenarios (figure 10.6). Emissions just shift between countries.

Ambitious unilateral climate policies implemented by large net fuel importers can trigger significant industrial and emissions leakage to fossil fuel–dependent countries. In the unilateral policy scenarios, the OECD countries and middle-income net fuel importers, including China and India, implement much higher domestic carbon taxes to maintain the same global emissions as in the cooperative scenarios. FFDCs continue domestic climate policies just to meet their initial NDC goals. This triggers a chain of macroeconomic pressures on fuel producers and exporters. First, by imposing carbon taxes, fuel importers capture a portion of exporters' resource rents and collect them as their own fiscal revenue. High carbon taxes in major fossil fuel importers increase fuel prices to their consumers, suppressing external fuel demand. The declines of export demand and/or producer prices reduce the exporters' opportunity costs of using fuels at home. Exchange rates of exporters' currencies also fall, reversing the Dutch disease and boosting the export competitiveness of their manufacturing industry (if it is sufficiently developed and competitive). In industrialized fuel-producing countries, a bulk of manufacturing output is concentrated downstream in the value chain of the extractive sectors. In the meantime, foreign competitors in energy-intensive industries are being prematurely retired at home by high unilateral carbon prices. Therefore, the emission- and energy-intensive industries in fuel-producing countries expand their market shares in the globally declining emission-intensive sectors, at the expense of the CPLs. Such traditional diversification away from reliance on fuel exports and toward reliance on downstream, fuel-intensive tradable products can be successful in the short to medium term. But it leads to accumulation of carbon-intensive produced capital, which is increasingly exposed to external technology and policy shocks of low-carbon transition and eventually to the tragedy of the horizon (Carney 2015; Peszko et al. 2020). Relatively new fuel exporters in Africa and Latin America or conflict-affected countries in MNA may not be able to cushion the external shock to fossil fuel wealth by reversing the Dutch disease, because they have not yet converted fossil fuel rents to well-developed manufacturing sectors. Unless these economies diversify their exports away from fuels, exchange rate depreciation arising from lower external demand by large fuel importers may push these countries back to dependence on mining, agricultural commodities, or timber, increasing environmental pressures on sustainable development.

Already industrialized natural gas and coal producers have stronger incentives to free ride and fall into the trap of traditional, emission-intensive diversification. Gas has multiple industrial uses, including in process heating, chemicals, fertilizers, hydrogen, and space heating. It can substitute for coal in power and for oil in transport. In contrast, oil is used mainly in transport and much less in petrochemicals and power. The simulations suggest that the comparative advantage of gas-intensive industries in FFDCs seems to persist in the noncooperative scenarios despite BCATs. Coal is mainly used in power generation where it faces competitive pressure from natural gas and renewables. Smaller quantities are used in steel and cement production, where coal is more difficult to substitute.

These findings paint a more complex picture of the vulnerability of different fossil fuel producers than simple divestment narratives often found in stranded assets literature. The multisectoral and dynamic nature of ENVISAGE, coupled with a detailed extractive sector model, illustrates that low-carbon transition poses additional challenges, not just for high-cost producers, but also for those that are further from the remaining demand, less diversified, and with limited access to resources. The ability to redirect fossil fuels from exports to domestic use by increasing the output of energy- and emission-intensive industries also makes a difference to sovereign risk and risk management strategies. Many fuel-producing and -exporting countries in Sub-Saharan Africa and Latin America and the Caribbean, as well as conflict-affected countries in MNA and the rest of Africa, may have limited capabilities to mitigate transition risk in this way. In contrast, fuel exporters that have already developed a heavy industrial base and value chains, such as the Gulf Cooperation Council countries, Mexico, or the Russian Federation, may be tempted to give their heavy industries a "free ride" on the global effort to mitigate climate change and try to continue generating wealth from fossil fuel reserves by stimulating domestic demand by downstream fuel-intensive industries and becoming "emissions havens." The simulations show that a credible threat of BCATs can be a sufficient deterrent to discourage such free riding for MNA and ECA, but only if policy makers were concerned more about the wealth of the entire society (figure 10.17) than about the wealth of gas and coal producers. For the countries that are captured by their extractive institutions (Acemoglu and Robinson 2012), BCAT may not be enough to encourage cooperation without additional incentives, such as financial and technology transfers, preferential trade and policy agreements, or stricter trade sanctions (Peszko, Golub, and van der Mensbrugghe 2019; Peszko, van der Mensbrugghe, and Golub 2020).

Dynamic analysis of resource rents suggests that the steep ramping-up of climate action in 2025 may be a much larger shock to resource owners and shareholders than a CGE model can simulate. For the oil and gas markets, it could be a shock comparable to the value destruction in 2014 and 2020, although some significant differences must be noted. First, the 2014 shock was an unexpected market price drop with no impact on demand. In contrast, the COVID-19 shock to fossil fuel rents in 2020 was driven by an equally unexpected and sudden drop but in demand because of pandemic lockdowns. In both historical cases, the impact was "external" and surprising, but once it happened it was expected to be temporary. Indeed, demand and prices rebounded after the shocks, restoring the future value of fossil fuel assets. In contrast, the shocks of low-carbon transition are driven by dedicated policy efforts; hence, the markets are more likely to lose hope for a future rebound of rents and returns. The future loss of fossil fuel asset value can be secular and permanent rather than just cyclical as in the past.

Competition and fights for market shares in declining industries are much more volatile and irrational than simulated in the CGE model, which assumes rational behavior of all economic agents and always pushes them to new equilibria after the shock. For coal owners and shareholders in coal companies, the impact can be unprecedented. The milder and short-term drop of global coal rents by 40 percent globally in 2013–15 caused a shockwave of mine closures in Europe and bankruptcies in the US coal mining industry, starting with the world's largest private coal company, Peabody Energy. The policy-induced annual drop in coal rents of 62 percent in five years simulated here suggests the possibility of a much deeper impact on the coal industry. With no hope for a future rebound of coal rents, which always happened in the past, the future shock to coal mining may be very serious. And this time it would also affect the coal mines in developing countries, including China and India, where mining communities are often more vulnerable than those in the Appalachian region in the United States or Silesia in Poland. The good news is that the policy-induced shocks are anticipated at least by those who want to believe they will prevail; hence, countries can better prepare to hedge the transition risks. The challenge for policy makers will be to give mining communities honest early warning and help them through a smooth *just transition* and facilitate the accumulation of a broader wealth base for their development.

The lower-income, fragile, and conflict-affected fossil fuel producers may need international assistance in the low-carbon transition. They have few alternative sources of short-term revenue that could be reinvested in a diversified portfolio of national wealth to create a more resilient and greener asset base for long-term resilient, sustainable, and equitable prosperity. As discussed earlier, reversing the Dutch disease may not help them in the absence of well-developed internationally competitive manufacturing sectors.

Conclusion

Low-carbon transition represents a material risk to the value of all fossil fuel assets. In 2018–50, under ambitious climate policies, global fossil fuel wealth may be US$4.4 trillion to US$6.2 trillion (13–18 percent) lower than in the reference scenario that reflects the expectations of fossil fuel owners. Globally, this amounts to only 13–18 percent less value than with the NDC-oriented reference scenario. In real life, however, without the gentle safeguards of the equilibrium conditions and perfect rationality of all agents assumed in the CGE model, the shocks can be much stronger. This could be especially true for the least prepared asset owners and those countries that have not developed internationally competitive manufacturing. Once extractive industries become widely perceived by investors as declining industries, the transition may be much more volatile and erratic than even past experience suggests. Competition between asset owners will intensify as demand shrinks and disruptive clean technologies capture more markets. Producers with low extraction costs, already sunk capital costs, lower upfront capital needs, better access to investors and developers, higher accumulated financial strength, lower leverage, and more highly developed export infrastructure will be in a more privileged position to maintain and even increase their fossil fuel wealth than others. Countries that are less dependent on fuel export revenues and have more diversified asset bases with which to compete internationally in terms of manufacturing goods and knowledge-intensive services will find it easier to navigate a low-carbon transition toward new sources of growth and comparative advantage.

The risk of low-carbon transition is unevenly distributed across fuels, countries, and asset owners. By fuel, oil assets represent the largest value at risk and gas the lowest, but in percentage terms, coal reserves are likely to lose the largest share of value and oil the least. By region, the highest fuel assets value at risk is in the MNA region, because of oil.

Rapid ratcheting up of carbon pricing may have very serious implications for coal wealth worldwide. In percentage terms, coal-intensive middle-income fuel importers and coal exporters risk the most. Cambodia, China, India, Indonesia, Mongolia, and several other coal-intensive countries will also need to prepare for downstream shocks in coal-intensive electricity generation. A policy-driven low-carbon transition can cause almost total collapse of coal mining industries. Coal-producing developing countries could experience a similar but faster collapse of coal mining than those experienced in the past by the European Union and the United States. The collapse of coal mining is not likely to cause systemic macrofiscal risk in any country because, unlike the case of oil and gas, even the largest coal producers do not depend on coal rents for tax and export revenues or as a growth driver. The largest risk of economic, social, and political disruptions is related to stranded workers in coal mining regions and coal-dominated power systems.

Exploratory policy scenarios can help understand the risks and uncertainties of low-carbon transition. They can also identify policy pathways to cooperation on climate change between fuel importers and exporters. The scenarios simulated here shed new light on the political economy of low-carbon transition and climate cooperation between countries with different path dependencies. Despite the likelihood that a noncooperative low-carbon transition would destroy more fossil fuel asset value, especially with BCAT, the self-interest to be a leader or a follower of climate action varies by country and fuel.

Fuel importers have economic incentives and capabilities to lead climate policies. They also have collective self-interest and market power to encourage fuel exporters to overcome their free-riding incentives with policies including BCATs, although for some gas and coal exporters this may not be enough to cooperate. The gains that CPLs would enjoy from global climate cooperation are more than enough to compensate for their loss of coal wealth, including in coal-intensive net fuel importers, like China and India.

Interestingly, large oil exporters, especially in MNA, also benefit from cooperative climate policies, especially if the counterfactual is an ambitious unilateral climate action by a large club of major oil importers with BCATs. The fundamental incentives of large oil exporters in cooperative climate policies still goes largely unnoticed in the literature and in public debates, although recent more proactive engagement of the Gulf Cooperation Council countries in cooperative climate initiatives suggests that their leaders begin to see that the risks of cooperation are lower than the risks of free riding.

Many gas and coal exporters may have relatively strong incentives to free ride on the unilateral climate policies of fuel importers. They benefit from domestication of emission-intensive heavy industry (emissions leakage) under the asymmetric climate policies. A credible threat of a BCAT imposed by importers could erase the benefits of free riding for many, although not necessarily all, large gas and coal producers. Low international fuel prices combined with high carbon taxes abroad encourage most industrialized gas and coal exporters to increase their market share in globally declining emission-intensive manufacturing and services. Additional incentives may be needed to encourage and enable cooperative climate policies by countries having strong comparative advantage in heavy industrial products (Peszko, Golub, and van der Mensbrugghe 2019; Peszko, van der Mensbrugghe, and Golub 2020). Pollution havens may be consistent with mitigation pathways toward 2°C and even some 1.5°C goals. Policy-driven yet still uncertain technology breakthroughs, for example in production and distribution of green and blue hydrogen, could eliminate the benefits of pollution havens, however.

The lower-income, fragile, and conflict-affected fossil fuel producers will need international assistance in the low-carbon transition. They have few alternative sources of short-term revenue that could be reinvested in a diversified portfolio of national wealth to create a more resilient and greener asset base for long-term resilient, sustainable, and equitable prosperity.

The CWON core accounts represent a conservative approach to the valuation of fossil fuel wealth, consistent with SNA-compatible standards of government balance sheets. In the climate policy scenarios, the value of oil and gas assets remains higher than in the CWON, although coal wealth in the CWON does not pass the low-carbon transition stress test. The reason is that the CWON uses rigorous, albeit conservative, SNA accounting principles and considers as assets only class A deposits that come from projects that were producing, those approved for development, and those justified for development (United Nations 2019) under market conditions prevailing in 2014–18, which were characterized by historically low fossil fuel prices. Furthermore, following the SNA/SEEA recommendations, the CWON valuation assumes that the average rents from 2014–18 will remain constant until 2050. In contrast, ENVISAGE, with its resource extraction module and endogenous formation of prices, production, and rents, also converts some proven, class B reserves to class A reserves and brings them into production when simulated market conditions allow. Future market conditions in the business-as-usual scenario (even with NDC pledges) are more conducive to fossil fuel wealth than on average in 2014–18; therefore, total fossil fuel asset value increases to US$34.2 trillion (compared to US$25.9 trillion in the CWON).

The values of the stranded fuel assets simulated here are broadly in line with the stranded assets literature, although comparison is difficult because of the literature's wide variety of approaches and rigor. This study contributes to a nascent literature that stress tests fossil fuel wealth with alternative policy pathways rather than emissions pathways (that is, carbon budgets on paper).

As the low-carbon transition drives down volumes of fossil fuel use, the noncompetitive producers will also be leaving market, inducing additional volatility in the global commodity prices. The last remaining fuel producers will increase their market power and may well be able to secure higher prices and extract higher rents and profits from the last producing reserves. Decoupling volumes from rents in the public discourse could create a much-needed space for less confrontational dialogue about low-carbon transition. The resource-rich nations would find it less threatening to engage in the dialogue on climate policies if they could expect that their total rents would be falling slower than their production volumes.

Notes

1. The key goal of the Paris Agreement is to limit global warming to well below 2 degrees Celsius, preferably to 1.5 degrees Celsius, compared with preindustrial levels.
2. By far, most scenarios available in the mitigation pathways literature assume alternative environmental constraints as inputs to the models (stabilize greenhouse gas concentrations over the 21st century, limit end-of-century radiative forcing to specific levels, or prescribe an overall limit on total cumulative carbon dioxide [CO_2] or greenhouse gas emissions over the 21st century, as a proxy for global-mean temperature rise over the year). Models are then optimized to achieve these objectives in a cost-effective manner (Rogelj, Shindell, et al. 2018;

Rogelj et al. 2019). In this chapter, the modeling approach applies a rarer logic. It assumes alternative policy instruments applied by certain country groups as explicit inputs to the model. The model produces an emissions pathway as an output of model simulations. The approach produces scenarios that may be more realistic and policy relevant but are neither globally nor intertemporally optimal. Nor do they guarantee the same stringency of carbon budgets or temperature outcomes as in scenarios in which these environmental variables are assumed to be constraints. Nonetheless, as explained later in the text, comparison with Intergovernmental Panel on Climate Change (IPCC) scenarios on the same terms (gross emissions of CO_2 in the same period) shows that the cumulative emissions calculated in the scenarios are in line with the carbon budget used in the 2 degrees Celsius–consistent mitigation pathways and even some 1.5 degrees Celsius–consistent scenarios found in the IPCC-related literature.

3. Except for unit rent, which is often smoothed over five or six years for asset valuation.

4. Detailed descriptions of the methodology and data sources are provided on the CWON website, https://www.worldbank.org/en/publication/cwon.

5. These can be accessed at the Global Trade Analysis Project databank, https://mygeohub.org/groups/gtap/envisage-docs.

6. For this study, ENVISAGE was not run in its integrated assessment mode, so avoided damages from climate change are not endogenously calculated and the impact of climate policy on GDP is by design negative compared with the baseline. It is also worth stressing that in the CGE models it is not the absolute figures but differences between countries, fuels, and policy scenarios that provide the most important insights.

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11

Wealth Accounting, Diversification, and Macrofiscal Management

James Cust and Alexis Rivera Ballesteros

Main Messages

- Wealth accounts provide data and indicators that can shed light on the sustainability of asset transformation and diversification. These can be used to inform macrofiscal management and policy making.
- Applying a natural capital lens to macrofiscal analysis finds that degrading the value of renewable natural capital has been associated with lower or declining total wealth per capita. Protecting and enhancing the value of renewable natural capital is associated with better economic performance overall.
- The abundance of nonrenewable natural capital in some countries raises special challenges for the sustainability of economic growth and investment, as rents are derived from depleting—and unsustainable use of—these assets. Transformation of those assets into human and produced capital is therefore an important part of the economic diversification process and can be tracked using wealth accounts.

Introduction

Natural capital abundance can represent an opportunity to accelerate economic development. However, countries that have large natural capital shares of total wealth may also face challenges associated with turning those assets into sustainable prosperity. These include challenges from resource exhaustibility and price volatility in countries that depend on nonrenewable natural resources, including oil, gas, and mineral wealth. Transforming depleting nonrenewable natural capital into a portfolio of assets has proven difficult (Venables 2016). Renewable natural assets such as forests and fisheries are also prone to management challenges, where overconsumption can deplete their value—a phenomenon sometimes linked to the tragedy of the commons.

Long-run economic growth and sustainable prosperity depend on several important ingredients. According to the Commission on Growth and Development (2008), high-growth countries recorded high levels of investment and capital accumulation, relative to lower-growth countries.[1] Furthermore, where a country is depleting its nonrenewable natural capital, a sufficiently high share of the revenues generated should be reinvested to accumulate other assets—such as productive capital and human capital—to offset the asset value reduction from depletion. This principle is known as Hartwick's rule (Hartwick 1977).

Lower-income countries often have scarce human and productive capital (Collier et al. 2010). Therefore, natural capital offers an opportunity to generate additional revenue that the government or the private sector can invest in capital accumulation. But this depends on the transformation of natural assets into a more diverse portfolio of other assets. Countries face a choice about how to diversify their economies away from dependence on natural resources.

Diversification can be performed in different ways. A standard policy recommendation is for lower-income countries to boost the manufacturing export sectors, diversifying along the lines of the Asian Tigers and other rapidly industrializing economies. Studies like Hesse (2009) find a positive correlation between export diversification and welfare. Loungani (2017) indicates that increasing the tradability of services could help with diversification strategies in resource-rich countries and countries with a high concentration in manufacturing exports.

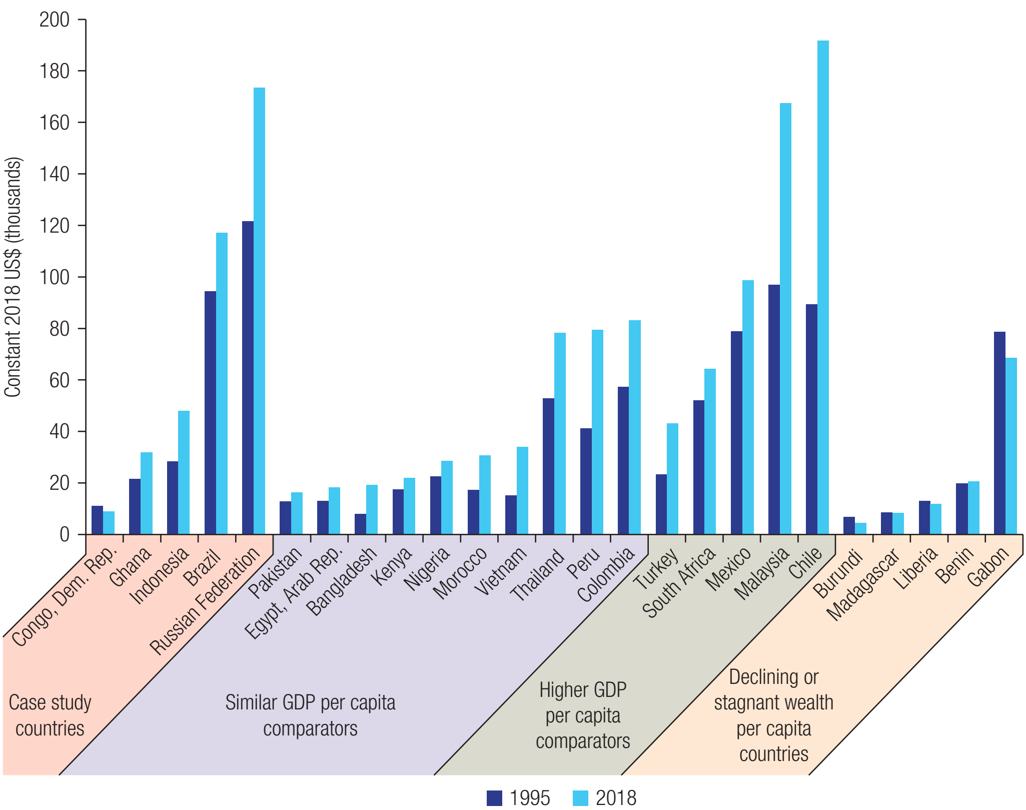
Diversification into other exports may be challenging for resource-rich economies. Ross (2019) finds that the historical diversification record among oil-exporting countries is abysmal. Between the 1990s and the mid-2010s, only 8 of 50 oil-rich countries ended the period more diverse—in export diversification terms—than they began it.[2] This is perhaps unsurprising given the extensive literature on the challenges of Dutch disease created by an appreciating real exchange rate, making traded sectors less competitive in the face of resource booms (Corden and Neary 1982). Empirical evidence supports this theory that resource abundance depresses other exports (Harding and Venables 2016). Such a challenge would apply to exportable services (which are traded) as much as to traditional export manufacturing or commercial agriculture.

Rather than targeting export diversification, diversification of assets or wealth may prove more feasible for resource-rich countries. Since government attempts to promote export diversification have proven challenging for countries abundant in natural capital, alternative proposals have been made. Baunsgaard et al. (2012) and Peszko et al. (2020) suggest, for example, that the design of spending policies in countries with a large endowment of nonrenewable natural capital should build human capital and renewable natural capital and reduce infrastructure gaps. In other words, this is diversification of assets or components of a nation's wealth (Gill et al. 2014).

This chapter provides a macroeconomic analysis of economic diversification progress. It then examines the role for a wealth accounting lens in the application of macrofiscal policy making and how that can aid governments targeting sustainable, broad-based development.

To contrast the evolution of these variables between countries with distinct levels of income and capital endowments, the chapter centers the analysis around 25 countries divided into four groups: (1) case study countries, (2) comparators with similar gross domestic product (GDP) per capita, (3) comparators with higher GDP per capita, and (4) countries with declining or stagnant wealth per capita. Figure 11.1 shows total wealth in 1995 and 2018 for the 25 selected countries. The criteria used to select these countries are described in detail in annex 11A at the end of this chapter. The analysis focuses on data between 1995 and 2018 to

FIGURE 11.1 Total Wealth per Capita, Selected Countries Used in the Analysis, 1995 and 2018



Source: World Bank staff calculations.

match the time frame of *The Changing Wealth of Nations* (CWON) core accounts data, with an emphasis on the 2000–2015 supercycle. The chapter defines the commodity boom periods based on the following periods: (1) the preboom period (2000–2003, when the price of oil was on average US$40 per barrel), (2) the boom period (starting in 2004, when the price of oil rapidly increased by more than 60 percent in less than a year, and ending in 2014, when the price of oil dropped by more than 50 percent in a year), and (3) the postboom period (2015–18, when the average price of oil was below US$60 per barrel).

This chapter is divided into five sections: (1) asset portfolio diversification versus export diversification, (2) sustainability and renewable natural capital, (3) adjusted net savings as a measure of sustainable wealth conversion, (4) macroeconomic and fiscal management, and (5) institutional capital. The first section starts by contrasting export diversification policies with economic diversification, arguing that a well-balanced asset portfolio could lead to more sustainable growth. Then it explores how asset portfolio diversification can be achieved, including investments in human and physical capital, reduction of dependence on fossil fuels, and reduction of the share of natural capital in total wealth. Investing in other assets, however, does not imply a reduction of natural capital per capita. Therefore, the second section describes the risks of increasing other assets at the expense of natural capital per capita and discusses weak and strong sustainability pathways. The section ends by raising the importance of renewable natural capital and the risks derived from its decline. Because savings are crucial when investing in other assets, the third section starts by explaining how wealth can be transformed into savings that will strengthen public finances and increase resilience during economic shocks. It then warns about the risks related to dependence on nonrenewable natural resource rents and the effect of excess depletion on net savings. These savings are transformed into public assets; therefore, the fourth section analyzes the performance of public finances, contrasting countries with different wealth endowments. It then evaluates the impact of the commodity boom in selected countries' government expenditure and fiscal balances. Because the process of accumulating capital or savings and meeting macroeconomic growth targets requires several years to substantialize, the fifth section examines the importance of good quality institutions and the benefits of early investments in institutional capital to contribute to sustained prosperity.

Asset Portfolio Diversification versus Export Diversification

Export diversification is a goal of many low- and middle-income countries. It has been a core driver of rapid economic growth and poverty reduction across East Asia in recent decades. This remains true for resource-abundant countries, which often seek to leverage their resource base as a platform for export diversification such as via cheap, subsidized energy or other kinds of resource-led industrial policy. Recent work (Ross 2019) finds, however, that export diversification can be very difficult to achieve.

The record among oil exporters is particularly poor. This comes as little surprise given the challenges to competitiveness posed by resource booms, which drive real exchange rate appreciation, a phenomenon known as Dutch disease (Corden and Neary 1982).

Some resource-rich countries that have achieved periods of sustained growth, however, have done so while securing a broader form of economic diversification by increasing their stocks of natural, human, and physical capital. Gill et al. (2014), for example, support this approach by showing that asset diversification should be accompanied by building better economic institutions to stabilize public finances, reduce volatility, invest in education and infrastructure, and encourage productivity. Successful developing countries have managed to transform their resource rents into human and physical assets that will help them achieve a more sustainable future. As Gill et al. (2014) conclude, countries should diversify "naturally." The CWON provides measures to help determine the composition of nations' total wealth and how it has changed over time.

A successful policy for sustainable economic growth might target asset portfolio diversification over export diversification by reducing the share of natural capital in total wealth. This does not mean a decline in the dollar value of natural capital per capita; instead, it emphasizes increased investments in the expansion of human capital and other productive assets. Such investments can be financed from the proceeds of prudent resource management. Lederman and Maloney (2012, 13) argue that countries should focus not on growth- or diversification-promoting sectors but on policies that "raise the overall ability of a country to increase productivity and quality, and to move to more sophisticated tasks."

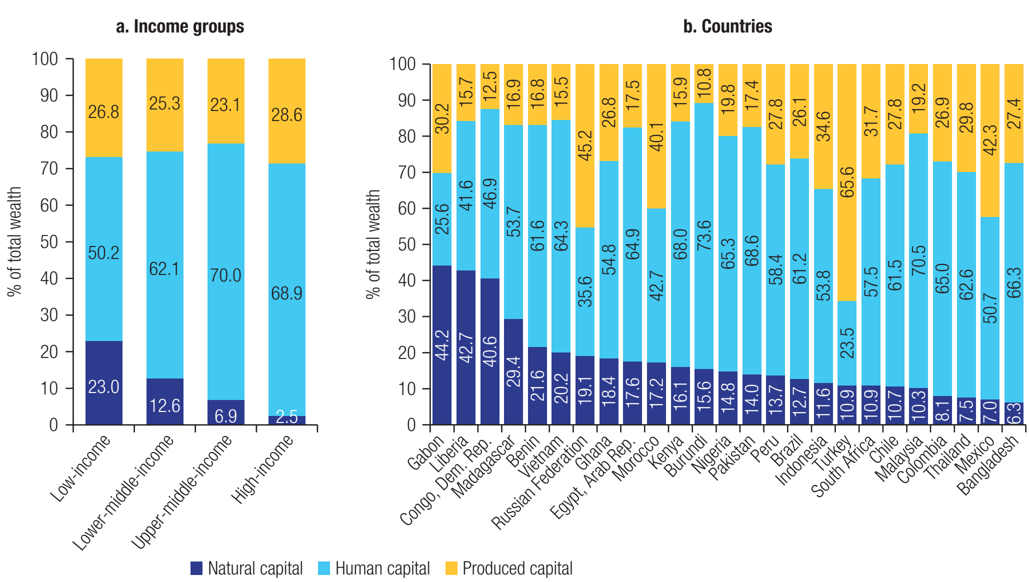
Peszko et al. (2020) explore asset diversification as a strategy that fossil fuel–dependent countries can pursue to manage the risks of low-carbon transition. They find that decarbonization policies initiated by fuel importers can unleash macroeconomic forces that encourage traditional export diversification of fuel exporters, by which they reduce reliance on export revenues from fossil fuel commodities and diversify into downstream, emission-intensive fossil fuel value chains. Such diversification represents a comfort zone for fossil fuel exporters, but it increases their exposure to multiple channels of low-carbon transition impacts, such as border carbon adjustments, disruptive technologies, and shifts in the preferences of consumers and investors. Asset diversification can be a long-term, sustainable alternative, but it is a challenging proposition because it requires discovery of new sources of comparative advantage and accumulation of unfamiliar produced assets and human capital, including new skills and capabilities (see also Ollero et al. 2019).

On average, countries with higher levels of income have a smaller share of natural capital in total wealth. Also on average, lower-income countries have a larger proportion of natural capital than any other asset. Since 2000, the average share of natural capital in total wealth has been at least two times larger in low-income countries than in high-income countries. Meanwhile, the average share of human capital in total wealth in high-income countries is now almost two times the share in low-income countries.

Economic development has been associated with declining shares of natural capital relative to other categories of wealth. Low-income countries, including the Democratic Republic of Congo, have an asset portfolio that is highly concentrated in natural capital, representing almost half the country's total wealth. Countries with higher GDP growth over the past two decades saw a faster decline in the share of natural capital, as other wealth accumulated. For example, Malaysia reduced its proportion of natural capital from one-fourth in 1995 to one-tenth of its total wealth in 2018, while its economy grew on average more than 5 percent each year. However, as shown in figure 11.2, there are also cases where low-income and lower-middle-income countries, including Bangladesh and Burundi, have a relatively small share of natural capital and a larger share of human capital. Asset endowments are different in these countries, and a reduction of the share of natural capital should not be the objective. Instead, the aim should be to increase the share of produced and human capital in total wealth, while also raising the value of natural capital in their asset portfolios. Indeed, for richer countries the absolute value (and value per capita) of natural capital tends to rise with the level of national income, even while its share in total wealth declines.

On average, countries with higher income per capita have a higher share of human capital in total wealth compared with their share of natural capital in total wealth. Between 1995 and 2018, as low- and middle-income countries grew wealthier, their share of human capital in total wealth increased. Some countries have been particularly successful in achieving this increase, but many countries are still struggling with this challenge.

FIGURE 11.2 Total Wealth Breakdown, by Income Group and Country, 2018

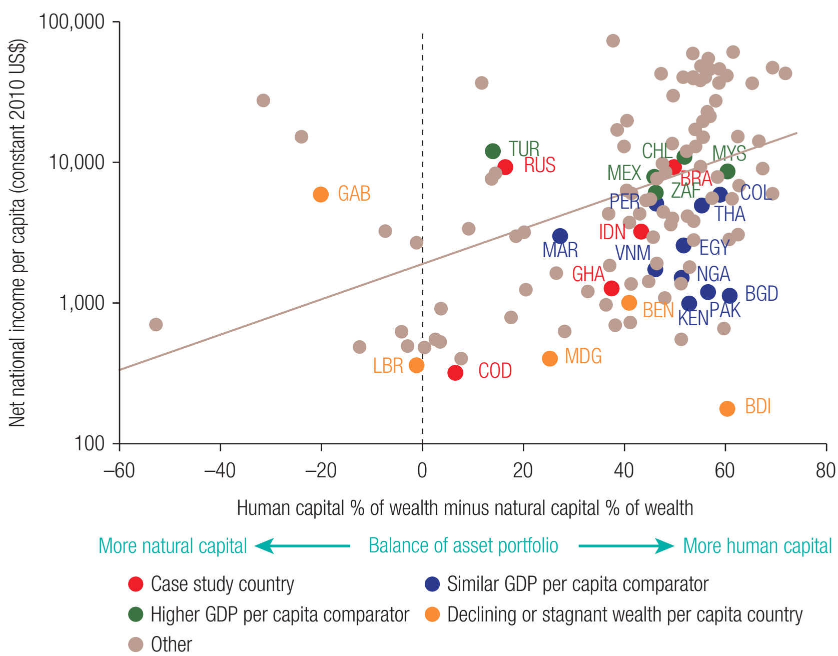


Source: World Bank staff calculations.

For example, Ghana's share of human capital in total wealth was about 38 percent in 1995 and 55 percent in 2018. By contrast, Gabon's share of human capital in total wealth dropped from 32 percent in 1995 to 26 percent in 2018. Other low-income countries, including Liberia, have increased the share of human capital in total wealth (from 29.7 percent in 1995 to 41.6 percent in 2018) at the expense of the share of natural wealth (which went from 55.4 percent in 1995 to 42.7 percent in 2018). However, its share of natural capital in total wealth is still 1 percentage point higher than the share of human capital (see figure 11.3). Bangladesh and Vietnam, which already had higher shares of human capital compared with natural capital, managed to increase their income per capita much faster than Liberia did.

There is a mixed picture among resource-rich countries in Sub-Saharan Africa. The share of human capital in total wealth has increased in the Democratic Republic of Congo, Ghana, and Nigeria while it has declined or has not changed in Cameroon, Gabon, and the Republic of Congo. Several Sub-Saharan African countries producing fossil fuels and minerals have made progress diversifying their asset portfolios by increasing their human capital share of total wealth. In the Democratic Republic

FIGURE 11.3 Net National Income per Capita versus the Difference between the Shares of Human Capital and Natural Capital, 2018

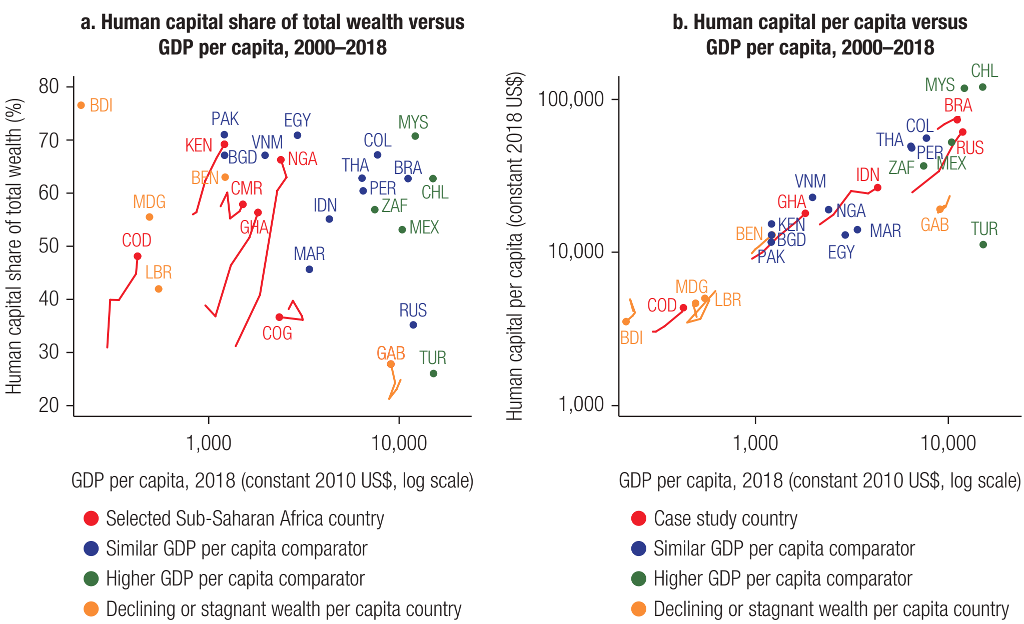


Source: World Bank staff calculations.
Note: See table 11A.1, in annex 11A, for definitions of country name abbreviations.

of Congo, Ghana, and Nigeria, the shares of human capital in total wealth increased by more than 10 percentage points between 1995 and 2018. For example, Ghana's share of human capital in total wealth increased from about 40 percent in 1995 to 57 percent in 2018, and in the Democratic Republic of Congo, this share increased from 30 percent to almost 50 percent during the same period. However, the share of natural capital in total wealth among other fossil fuel–producing countries, including Gabon and the Republic of Congo, has not changed, or has increased, resulting in a declining or stagnant proportion of human capital in total wealth. This is also reflected in their human capital per capita numbers. Human capital in the Democratic Republic of Congo, Ghana, and Nigeria in per capita terms did not stop growing between 1995 and 2018, and it surpassed the human capital per capita values of other higher-income countries (figure 11.4, panel a). However, as figure 11.4, panel b, shows, Gabon's human capital per capita decreased during the same years, similar to what happened with other declining wealth per capita countries, including Burundi and Liberia.

The quality of human capital accumulated by resource-rich countries may vary depending on the type of natural resources they produce and the configuration of their productive sectors. For example, Kuralbayeva and Stefanski (2013) suggest that resource windfalls will shift labor from manufacturing to nonmanufacturing activities, with the most skilled in the

FIGURE 11.4 Human Capital versus GDP per Capita



Source: World Bank staff calculations.
Note: The lines show the trend of values in 2000, 2005, 2010, and 2015, ending in 2018 (indicated by a dot). See table 11A.1, in annex 11A, for definitions of country name abbreviations. Abbreviations not listed in table 11A.1 include CMR (Cameroon) and COG (Republic of Congo). GDP = gross domestic product.

manufacturing sector remaining there and increasing the productivity of the sector but decreasing productivity in others. Nonrenewable natural resources—such as oil—can also impact the quality of human capital. Ross (2008) found that oil production reduces the female labor force and thus reduces its political influence. This can have an impact on gender imbalance and enable more patriarchal norms and institutions. At the same time, oil production in countries with poor governance can drive a higher demand of law or business jobs rather than engineering-related jobs because the former might have better access to rents (Ebeke, Omgba, and Laajaj 2015). This labor specialization might have long-term effects in productivity and the generation of future jobs. The topic is explored in more detail in chapter 12.

Sustainability and Renewable Natural Capital

In the process of asset portfolio diversification, a decrease in the share of natural capital in total wealth does not mean a decrease in the value of natural capital in per capita terms. Economic development and diversification of the asset portfolio might imply a reduction in the share of natural capital in total wealth. Ghana's share of human capital in total wealth increased, while its natural capital share decreased. However, its natural capital per capita went from US$6,000 in 1995 to a peak of US$9,000 during the 2004–14 commodity boom and dropped again to US$6,000 in 2018. Other countries reduced the natural capital share of total wealth but improved their value of natural capital per capita. For example, in Chile, the share of natural capital in total wealth dropped from 16 percent in 1995 to 11 percent in 2018, but its natural capital per capita increased from US$15,000 to US$21,000.

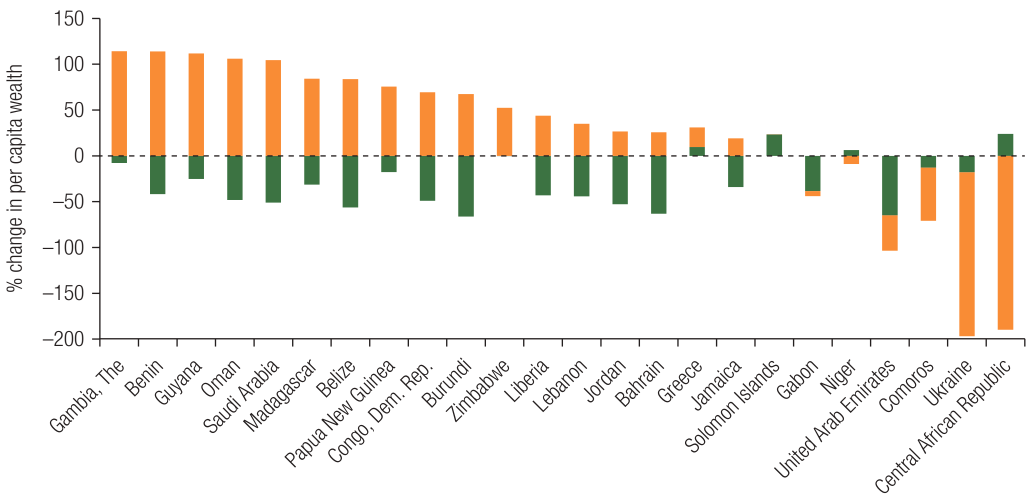
This process can also be seen clearly in countries that are less dependent on nonrenewable wealth. For example, the share of natural capital in total wealth in Bangladesh dropped by half, from 12 percent in 1995 to 6 percent in 2018, but natural capital per capita increased from US$1,000 in 1995 to $1,200 in 2018.

Poor overall wealth performance can be associated with declining natural capital. The situation is less optimistic in countries with declining or stagnant wealth per capita. In 16 of the 26 countries, human and produced capital per capita have increased at the expense of natural (mainly renewable) capital per capita. These countries are shown in the first bars from left to right in figure 11.5. In these countries, including Benin and Madagascar, where human and produced capital per capita have improved, renewable natural capital per capita has dropped. In six other countries, not only has renewable natural capital per capita declined, but human and produced capital per capita have declined as well.

Strong and Weak Sustainability

There are different ways to think about the overall sustainability of an economy. This analysis uses the terminology based on the work of Hartwick (1977) and Solow (1974), distinguishing between "weak" and "strong"

FIGURE 11.5 Change in Renewable Natural Capital versus Human and Produced Capital per Capita in Countries with Declining or Stagnant Per Capita Wealth, 1995–2018



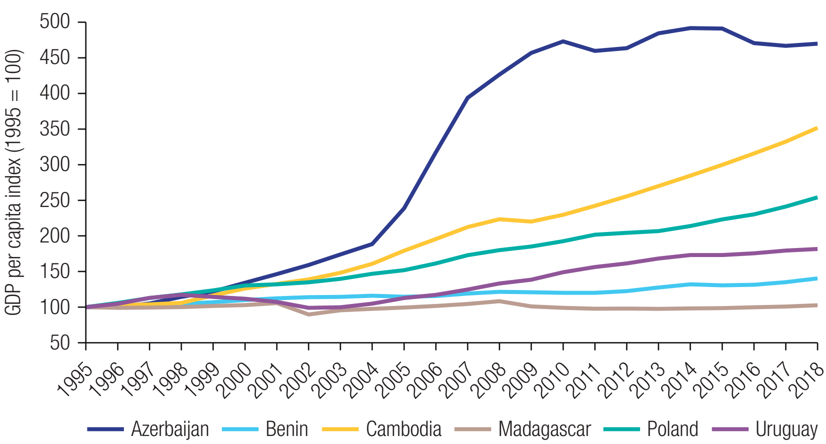
Source: World Bank staff calculations.
Note: Tajikistan and Moldova are not included because the percentage change in their human capital per capita is relatively high (–443 and –1,458 percent, respectively). The change in nonrenewable natural capital per capita is not shown since the variation among countries is high: zero in four countries (Belize, the Comoros, The Gambia, and Lebanon) and greater than 100 percent in eight other countries (including Madagascar and the Solomon Islands).

sustainability pathways. Weak sustainability refers to the process of capital exchange between human (or produced) capital and natural capital, a process in which natural capital might be exploited to generate economic output, some of which can be reinvested to help accumulate human (and produced) capital (Dasgupta 2004, 2007). This approach assumes that substitutability of physical and human capital for natural capital is relatively feasible; therefore, degradation of natural capital is not a first-order concern, so long as material well-being increases (Pezzey and Toman 2002). Strong sustainability implies that natural capital should remain constant or grow while human (or produced) capital increases over time (Davies 2013). Furthermore, strong sustainability typically is concerned with nature measured using physical indicators, rather than asset values—the CWON wealth accounts only provide insight into the latter. There is a debate between weak and strong sustainability proponents about which of these pathways maximizes the present value of future utility (Pezzey and Toman 2002), especially given major concerns about environmental tipping points, critical natural capital, irreversible loss of biodiversity, and climate change. However, the purpose of this analysis is not to contribute to this debate but to illustrate how the CWON wealth accounts can be a tool to examine different aspects of sustainability. This chapter does so by contrasting the pathways followed by selected countries and the impacts on different categories of wealth and natural assets.

Degrading the value of renewable natural capital has been associated with lower or declining total wealth per capita. For example, countries that have seen a decline in their wealth per capita have seen increasing human capital per capita, but this is sometimes at the expense of their renewable natural capital. This has also resulted in a decline in GDP growth during the same years. For example, in Benin and Madagascar, per capita wealth declined or was stagnant over 1995–2018. In both countries, human capital was at least 20 percent higher in 2018 than in 1995, but renewable natural capital declined by more than 30 percent (figure 11.5). At the same time, in Benin and Madagascar, annual GDP growth was on average 2 and 3.8 percent, respectively, between 1995 and 2018.

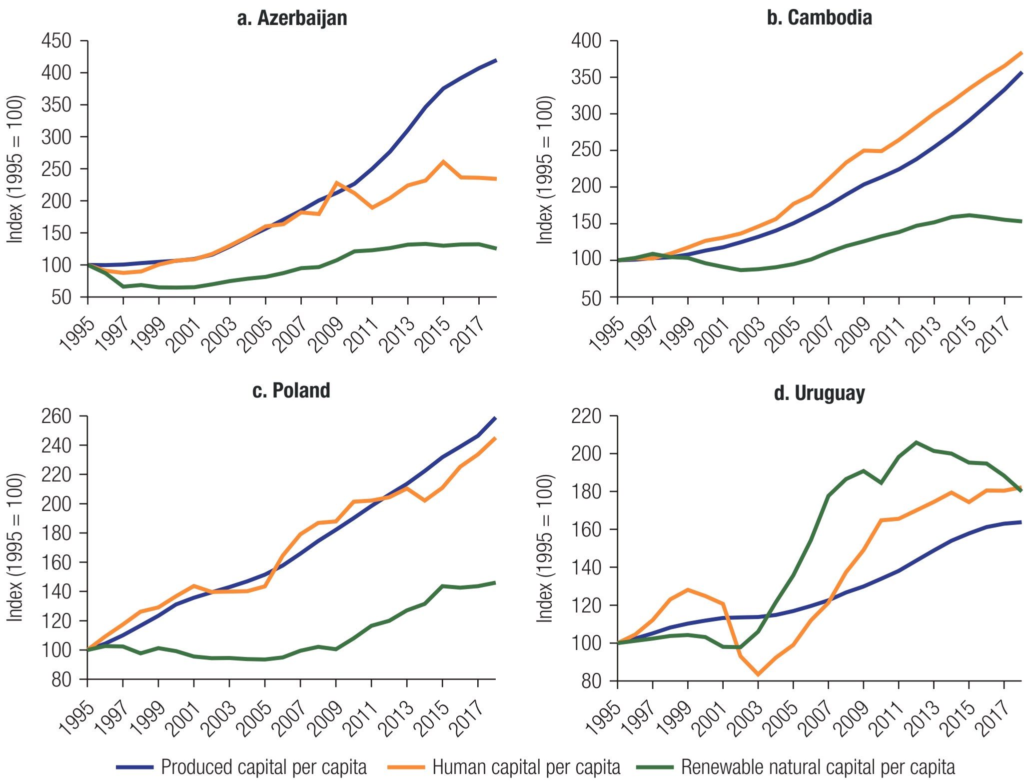
Protecting and enhancing the value of renewable natural capital is associated with better economic performance overall. For example, GDP per capita in Azerbaijan and Cambodia tripled between 1995 and 2018, while per capita GDP in Benin and Madagascar increased less than 50 percent over the 23 years (figure 11.6). In Azerbaijan and Cambodia, produced and human capital more than doubled, while renewable natural capital per capita did not decline (figure 11.7). By contrast, while produced and human capital per capita increased in Benin and Madagascar, their renewable natural capital per capita dropped (figure 11.8). Similarly, in high-income countries that have invested not only in their human and produced capital but also in their renewable natural capital, including Poland and Uruguay, GDP per capita was at least two times higher in 2018 than in 1995 (figure 11.7). The GDP per capita growth in these two high-income countries helped them move from the middle-income to the high-income group of countries according to the World Bank classification.

FIGURE 11.6 Annual Indexed GDP per Capita, Selected Countries, 1995–2018



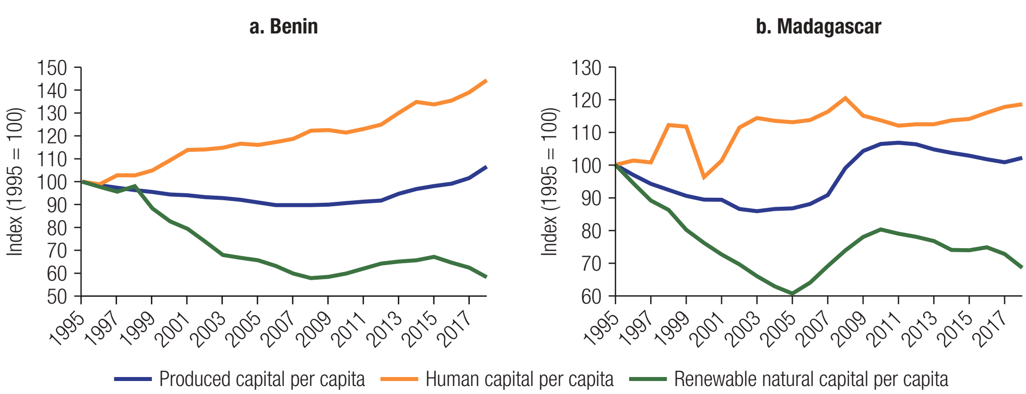
Source: World Bank staff calculations.

FIGURE 11.7 Annual Indexed Per Capita Wealth, Selected Countries with Growing GDP per Capita, 1995–2018



Source: World Bank staff calculations.

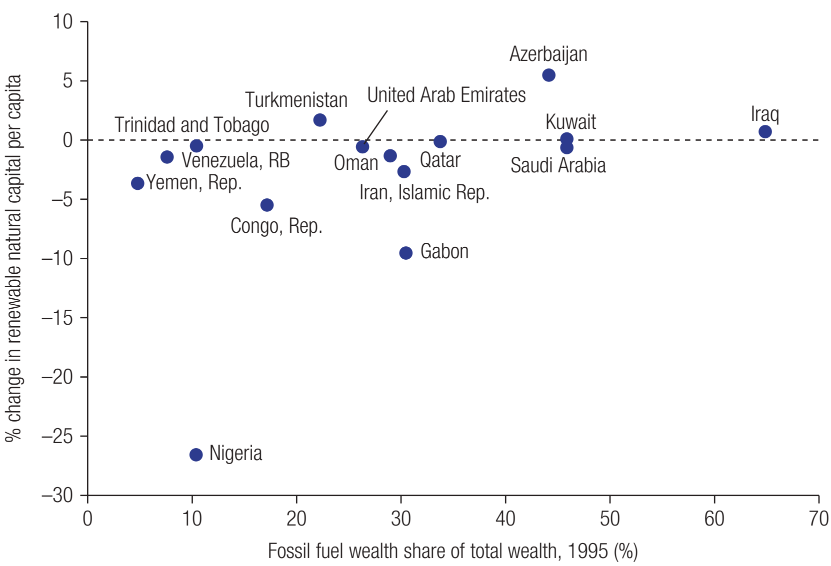
FIGURE 11.8 Annual Indexed Per Capita Wealth, Selected Countries with Declining or Stagnant Per Capita Wealth, 1995–2018



Source: World Bank staff calculations.

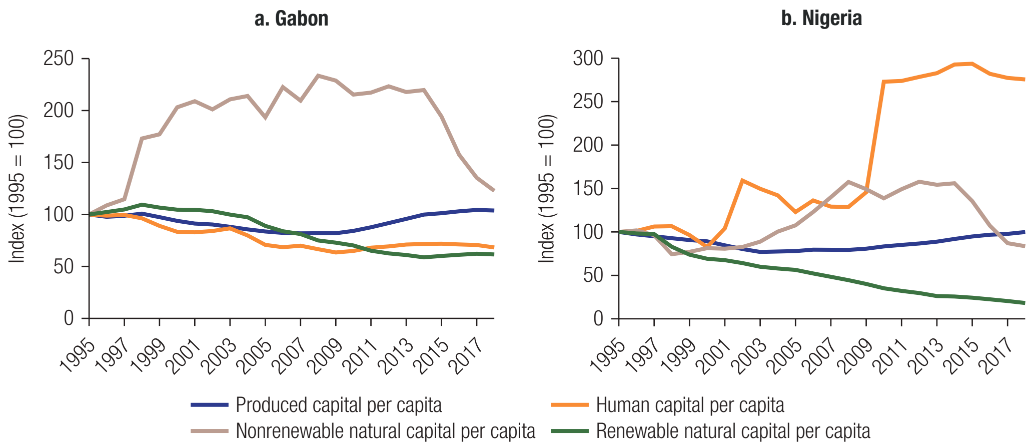
Renewable natural capital per capita has also declined or stagnated in some fossil fuel–producing countries, including Gabon and Nigeria. The first section of the chapter discussed how nonrenewable resource rents and nonrenewable natural capital declined after 2014 in countries that produce fossil fuels. But in several of these countries, renewable natural capital is following the same trend. Countries that have been producing fossil fuels since 1995 have also reported a decline or slow growth in their renewable natural capital per capita between 1995 and 2018 (figure 11.9). Two Sub-Saharan African countries—Gabon and Nigeria—are examples of this decline in multiple types of wealth. Although their nonrenewable wealth (mainly from fossil fuels) increased by more than 30 percent during the 2004–14 commodity boom (in part due to newly discovered deposits and the increase in fossil fuel prices), this nonrenewable wealth dropped below preboom levels after 2015. At the same time, these countries had among the largest declines in renewable natural capital per capita. Gabon dropped from US$1,400 to US$1,200, and Nigeria dropped from US$3,000 to US$1,300 in fewer than five years. The decline of these assets in turn affected the countries' total capital per capita, especially after 2015 (figure 11.10).

FIGURE 11.9 Change in Renewable Natural Capital per Capita in Countries Whose Share of Fossil Fuel Wealth in Total Wealth Was Greater than 5 Percent in 1995, 1995–2018



Source: World Bank staff calculations.

FIGURE 11.10 Annual Indexed Per Capita Wealth in Gabon and Nigeria, 1995–2018



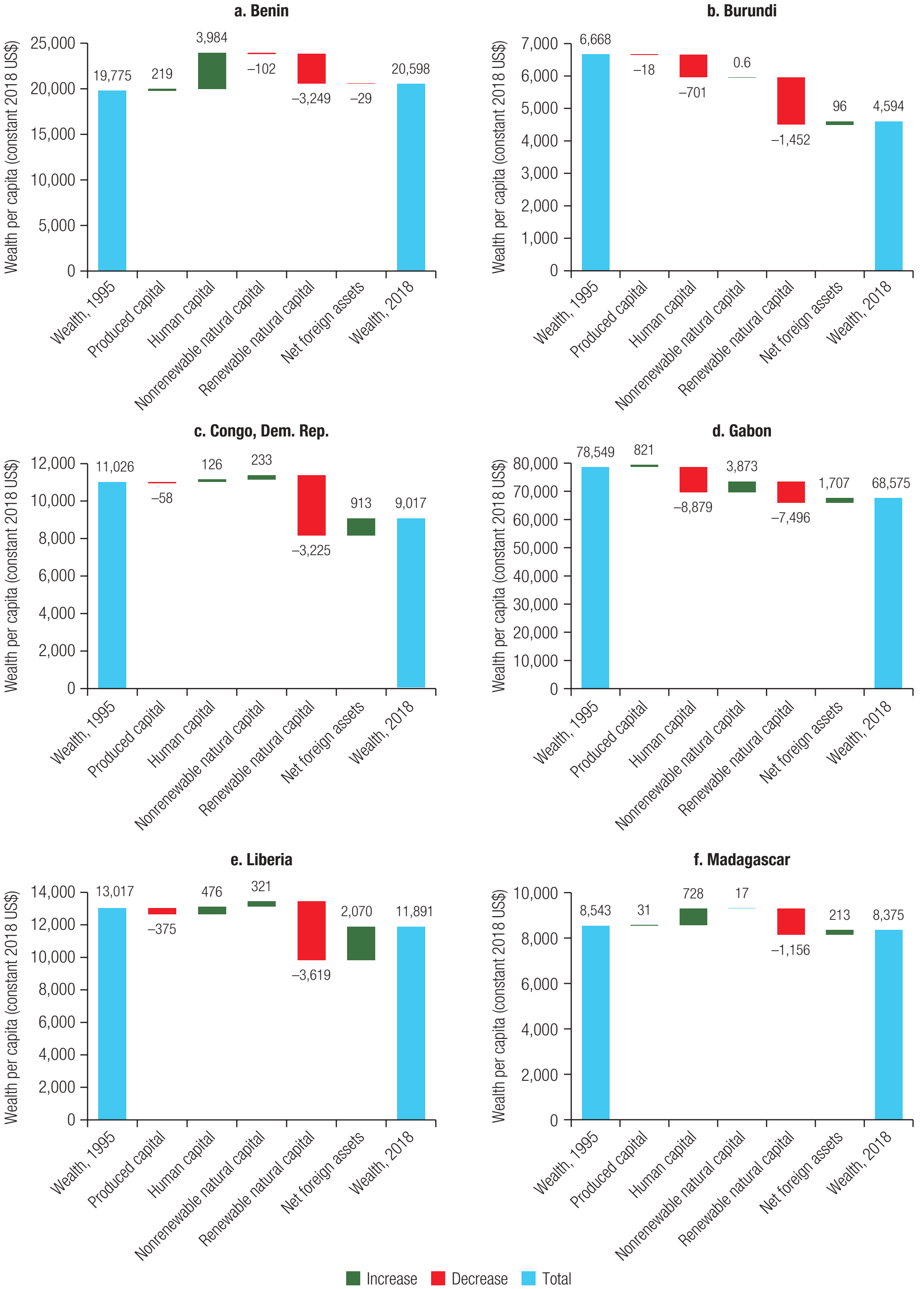
Source: World Bank staff calculations.

The decline of renewable natural capital per capita has been the main driver of the decline in per capita total wealth in half of the aforementioned Sub-Saharan African countries. Elsewhere, Tajikistan's large decline in total wealth per capita was driven mainly by a reduction in produced capital per capita, and in countries in the Middle East and North Africa, declining wealth per capita was driven by reductions in human capital and nonrenewable natural capital per capita. However, in 7 of the 11 Sub-Saharan African countries with declining or stagnant wealth per capita, the deterioration of renewable natural capital per capita is the main cause of the decline in total wealth per capita. Six of them have the largest declines in renewable natural capital per capita, along with Belize, Guyana, and Moldova. These countries are Benin, Burundi, the Democratic Republic of Congo, Gabon, Liberia, and Madagascar (displayed in figure 11.11). In these countries, the loss of renewable natural capital reached at least 10 percent of total per capita wealth in 1995. The main causes of this decline include loss of forest assets and loss of value of croplands.

Adjusted Net Savings as a Measure of Sustainable Wealth Conversion

GDP growth is the most widely used macroeconomic indicator for adjudicating broad economic progress. However, this typically is examined without reference to the evolution and composition of the underlying economic variables, such as the asset portfolio or a nation's wealth. Typically, a nation's wealth is formed by assets that turn into income (net national income). One part of these assets and income is consumed and another

FIGURE 11.11 Change in Wealth per Capita, by Asset, Selected Countries in Sub-Saharan Africa, 1995–2018



Source: World Bank staff calculations.
Note: Wealth per capita = total wealth divided by total population.

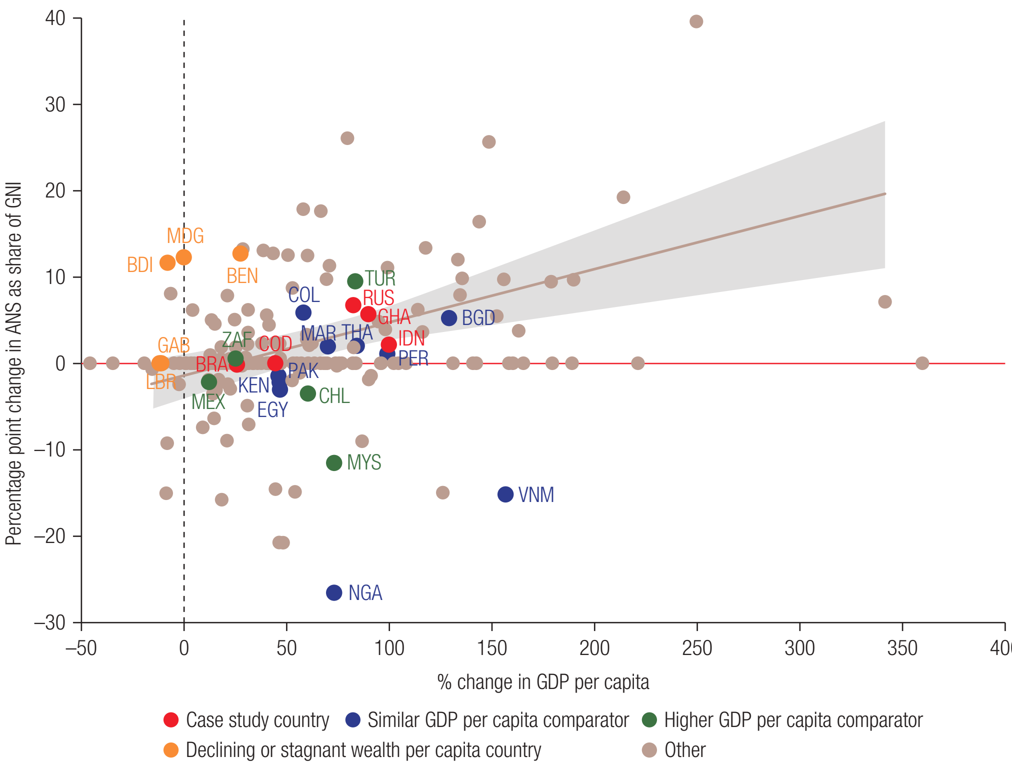
part is saved. However, in developing countries, the empirical evidence suggests that the consumption of these assets, mostly natural resources in some countries, can comprise a large share of the net national income. Sometimes this consumption or depletion of assets exceeds 50 percent of net national income, deteriorating the country's genuine savings.

According to Lange, Woden, and Carey (2018), aggregate measures of national wealth are closely linked to future well-being. A policy-relevant wealth indicator is an adjusted measure of net savings. The latest estimations of adjusted net savings (ANS) are based on the methods described in Lange, Woden, and Carey (2018), calculated as the total of a country's gross national savings minus consumption of fixed capital, plus education expenditure, minus subsoil resources depletion (fossil fuels and minerals), minus net forest depletion, and minus carbon dioxide and particulate emissions damage. These measures are usually expressed as a percentage of gross national income (GNI), which is the sum of value added by all resident producers plus any product taxes, minus subsidies not included in the valuation of output, and plus net receipts of primary income from abroad. The World Bank has published national-level ANS since 1999.

ANS can be used as an alternative measure of sustainable wealth conversion and as an indicator of how sustainable economic growth may be. There was a positive relationship between the percentage point change in ANS as a share of GNI and the percentage point change in GDP per capita between 2000 and 2018 (figure 11.12). For example, in Armenia and Latvia, where GDP per capita increased more than 100 percent, the share of ANS in GNI increased by more than 10 percentage points. By contrast, in Belize and Jordan, where GDP per capita had a percentage growth rate below 15 percent, the change in the share of ANS in GNI was negative during the same years. Yet in several countries with abundant nonrenewable resources and GDP per capita growth above 50 percent, the share of ANS in GNI declined more than 20 percentage points (for example, Guinea and Nigeria). The decline in ANS in countries with increasing GDP per capita comes from the fact that their depleted assets have not been transformed into human and physical capital, violating Hartwick's rule (Hartwick 1977), thus compromising the country's sustainable economic growth. When natural resource depletion is not used to invest in other assets in the wealth portfolio, countries' gross savings might not be enough to compensate this depletion, resulting in negative net savings.

Natural resource depletion has been the main driver of ANS decline in some lower-income countries. Comprehensive wealth accounts can be useful for shedding light on this. Recent work conducted by the World Bank has used the ANS approach to evaluate the net benefits generated from mining in Southern African countries (World Bank 2019). This report looks at the costs of mining, such as wealth depletion and pollution, as well as the benefits, including income, jobs, export revenues, and links to other sectors. This analysis allows the estimation of the "net benefits" once costs (including depletion) are subtracted from benefits, followed by the evaluation of how much of the income was being saved (that is, ANS).

FIGURE 11.12 Relationship between Change in ANS and Change in GDP, 2000–2018

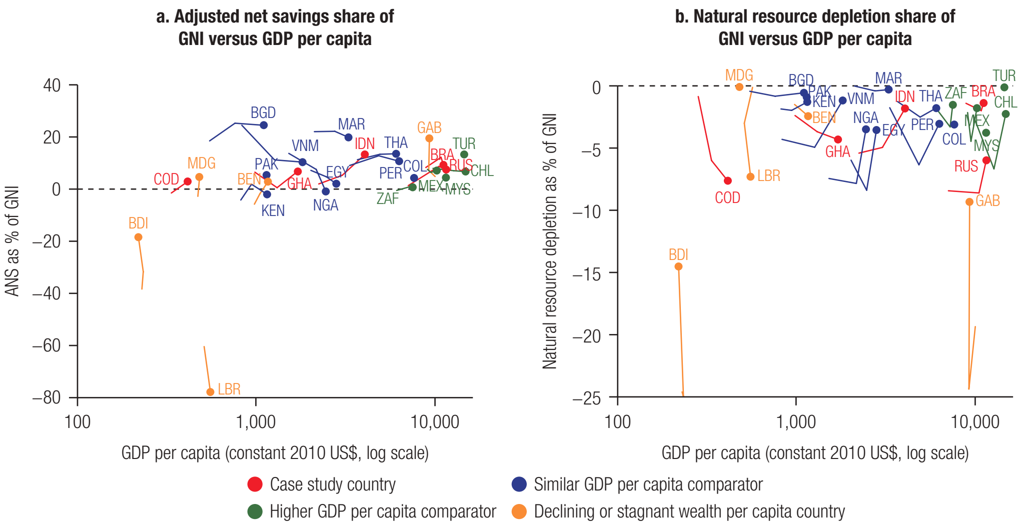


Source: World Bank staff calculations.
Note: The red line divides countries that improved their ANS as a percentage of GNI between 2000 and 2018 (upper) and countries that decreased it (lower). See table 11A.1, in annex 11A, for definitions of country name abbreviations. ANS = adjusted net savings; GDP = gross domestic product; GNI = gross national income.

Although depletion of natural wealth can generate wide benefits to the economy, accelerated depletion can also reduce the rate of ANS and impact long-term growth if it is not carefully reinvested. For example, Liberia's ANS fell from –60 to almost –80 percent of GNI in 2018, as shown in figure 11.13. Most of this decline was driven by an increase in natural resource depletion (mainly from forest resource depletion). At the end of the 2004–14 commodity boom, GDP growth rates in Liberia fell to negative numbers.

Negative ANS resulting from increasing nonrenewable resource depletion implies insufficient conversion into other assets. Countries with large reserves of fossil fuel and/or mineral resources consume these, aiming to transform them into income that will lead to growth and development. However, these resources can be depleted in an unsustainable manner that will eventually impact countries' long-term growth. For example, in the early 2000s, before the commodity boom, Ghana reached ANS shares of GNI above 10 percent, but as fossil fuel and mineral

FIGURE 11.13 Adjusted Net Savings and Natural Resource Depletion, 2000–2018

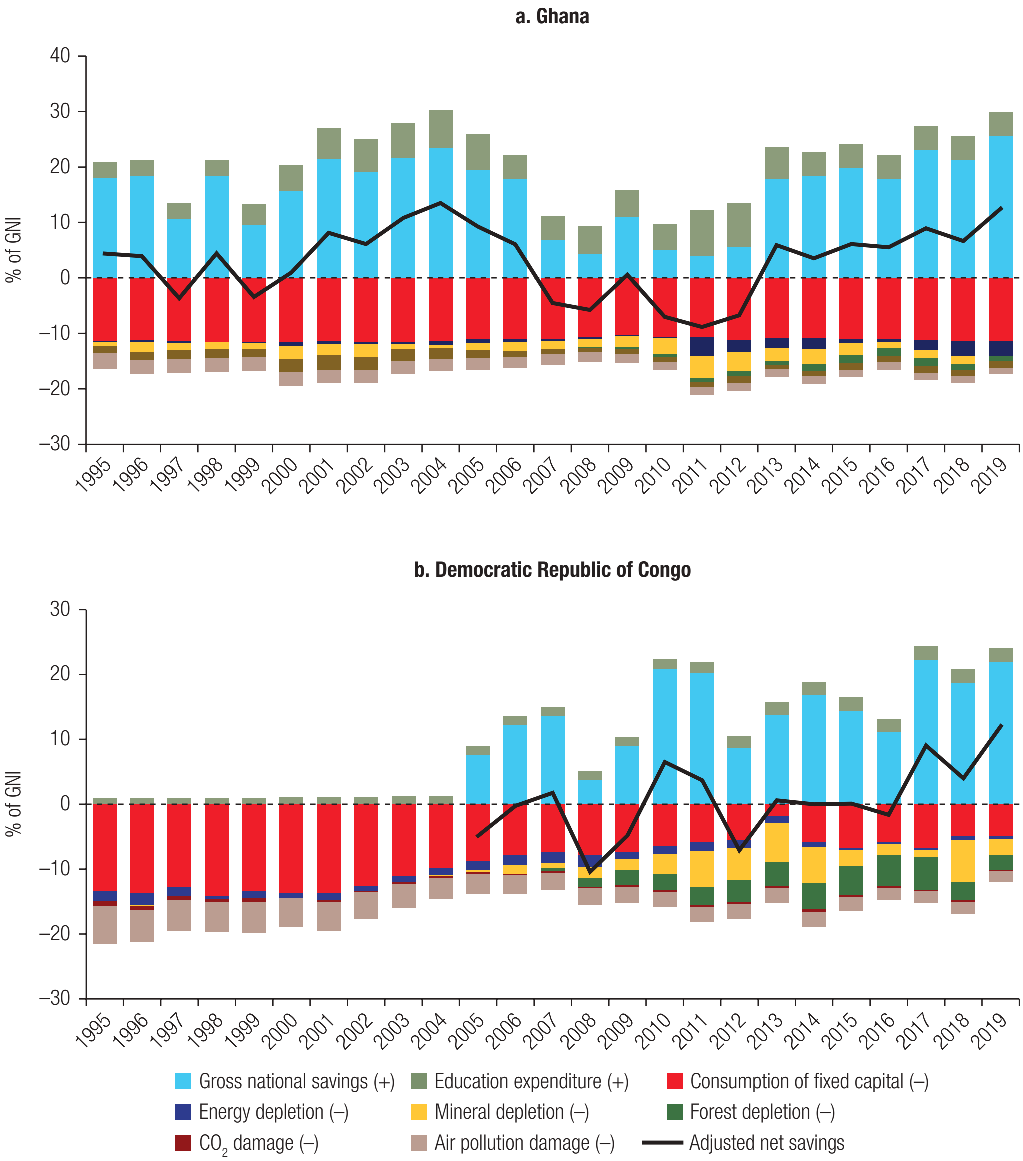


Source: World Bank staff calculations.
Note: The lines show the trend of values of the averages over 2000–2003, 2004–14, and 2015–18 (indicated by a dot). See table 11A.1, in annex 11A, for definitions of country name abbreviations. ANS = adjusted net savings; GNI = gross national income.

production increased during the boom, depletion rates increased and the country's ANS dropped below zero, particularly between 2007 and 2012 (figure 11.14, panel a). Although Ghana's GDP reached growth rates above 8 percent, driven by the booming fossil fuel sector, after the boom ended annual growth quickly dropped below 5 percent. Similarly, the Democratic Republic of Congo, which was growing above 6 percent per annum during the commodity boom years, reached negative values of ANS percentage of GNI. And while its ANS percent of GNI recovered thanks to increasing gross savings, GDP growth rates did not go back to boom levels (figure 11.14, panel b).

Nonrenewable natural resource depletion is not the only problem. In addition to the depletion of nonrenewable resources and a decrease in gross national savings, air pollution and carbon dioxide damage are pushing the share of ANS in GNI close to zero in two of the largest economies in Sub-Saharan Africa. Over the past two decades, Nigeria's air pollution damage and South Africa's carbon dioxide damage have been negatively impacting ANS. Estimates suggest that this damage could be as concerning as fossil fuel and mineral resource depletion for savings sustainability. Nigeria's fossil fuel depletion has fluctuated over the past 20 years, peaking during the first and last years of the commodity boom. After the 2014 oil price shock, depletion of fossil fuel's percentage of GNI dropped, but air pollution damage remained constant (figure 11.15, panel a). South Africa has neither significantly increased depletion nor decreased gross savings, but damage from carbon dioxide has reached more than 5 percent of GNI (figure 11.15, panel b). This carbon dioxide damage is an estimate

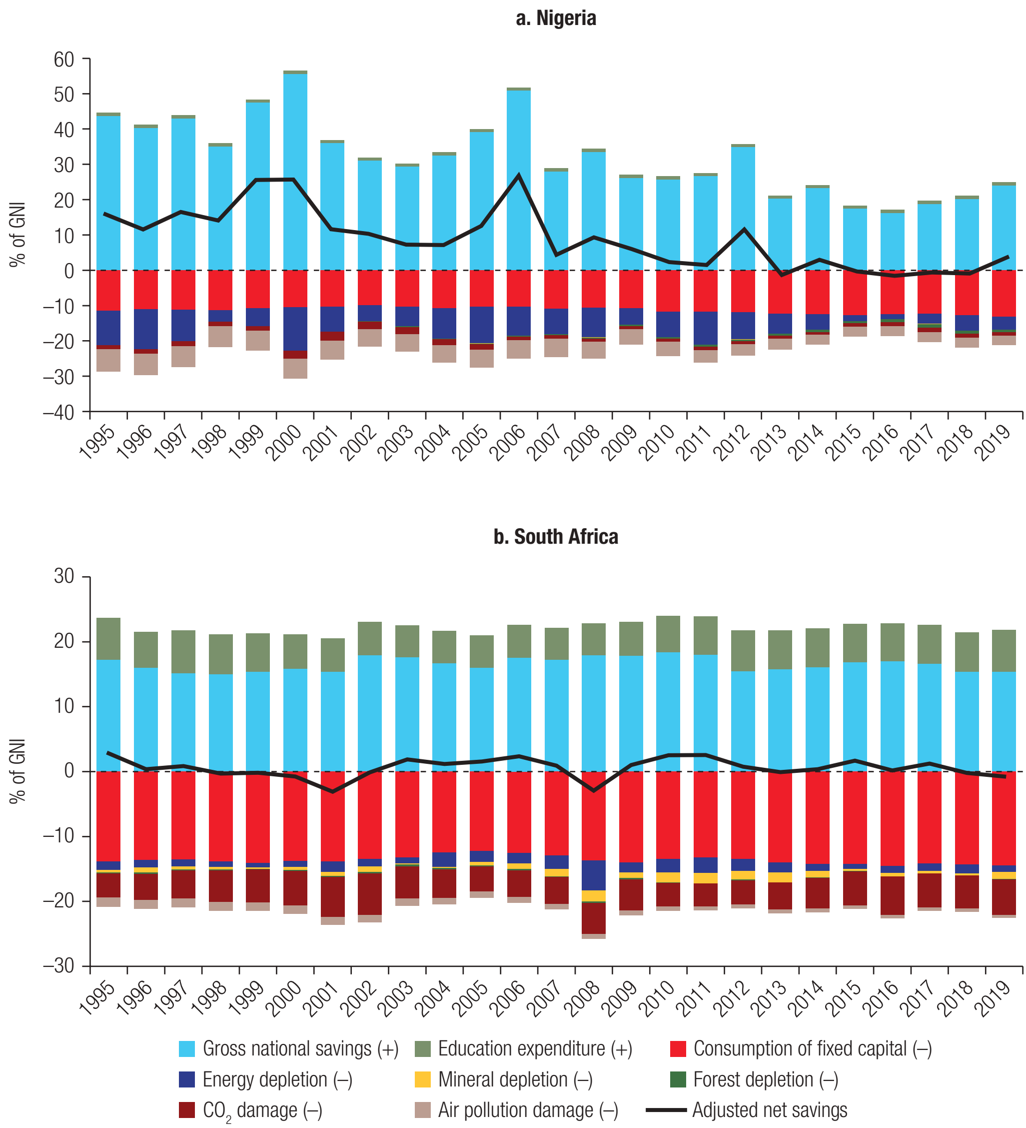
FIGURE 11.14 Adjusted Net Savings Components in Ghana and the Democratic Republic of Congo, 1995–2019



Source: World Bank staff calculations.

Note: Energy depletion includes oil, gas, and coal. Gross and adjusted net savings data not available before 2005 for the Democratic Republic of Congo. GNI = gross national income.

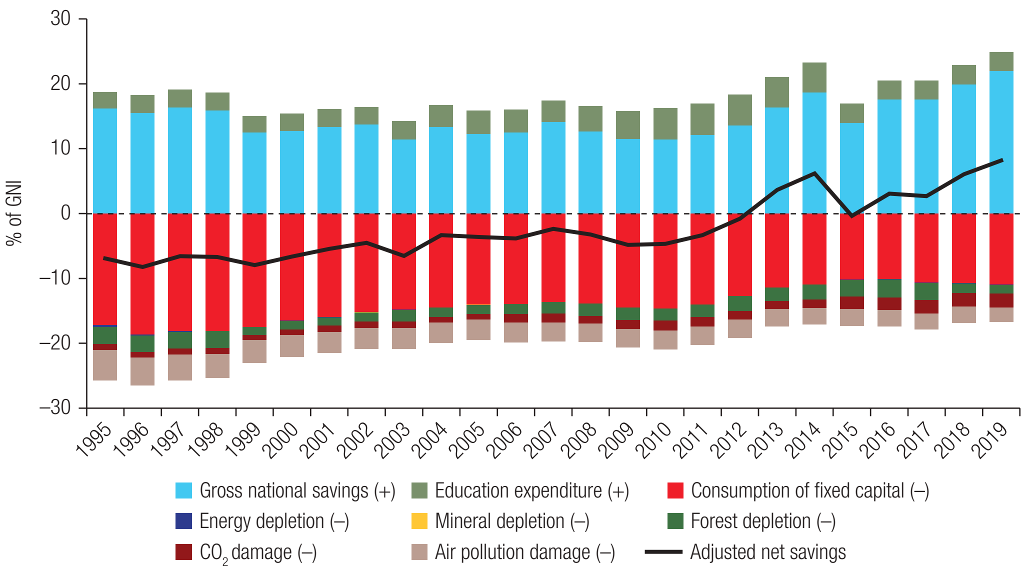
FIGURE 11.15 Adjusted Net Savings Components in Nigeria and South Africa, 1995–2019



Source: World Bank staff calculations.
Note: Energy depletion includes oil, gas, and coal. GNI =gross national income.

resulting from multiplying the cost of US$20 per ton of carbon (unit damage in 1995 US$) by the number of tons of carbon emitted. Its negative impact on South Africa's savings has prevailed over a decade, and the increasing share after 2015 is pushing net savings below zero, reaching –0.8 percent in 2019. The World Bank (2017) published a carbon tax guide to propose instruments that can help reduce this damage. The guide suggests, for example, that carbon taxes can be used as additional government

FIGURE 11.16 Adjusted Net Savings Components in Benin, 1995–2019



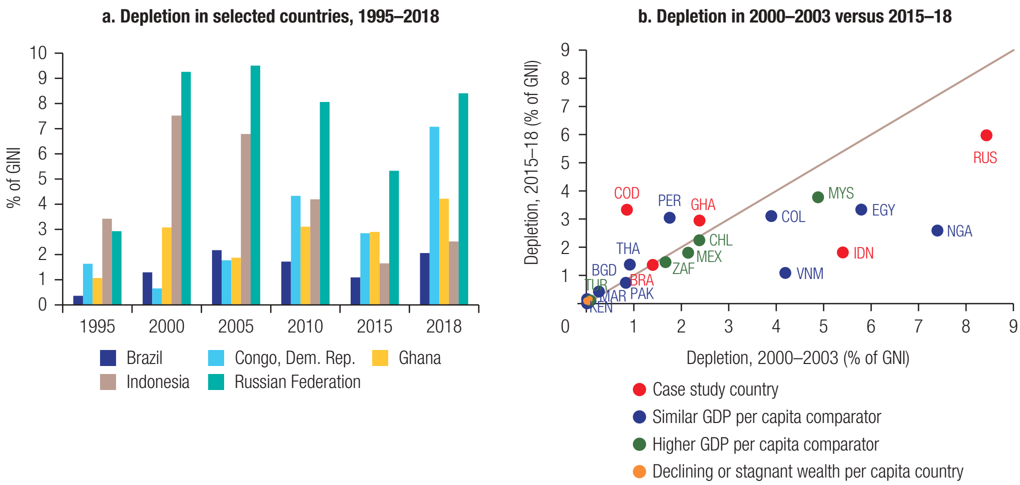
Source: World Bank staff calculations.
Note: Energy depletion includes oil, gas, and coal. GNI =gross national income.

revenues to support climate-related initiatives that can increase renewable natural capital or be invested in human or physical capital.

Countries with declining or stagnant wealth per capita need to increase gross saving rates to improve the share of ANS in GNI. Other countries that depend less on nonrenewable wealth, including Benin, do not have increasing depletion rates of fossil fuels or minerals, and they may not be depleting their forests at a high rate. However, some of these countries are not showing growth in their gross savings; therefore, any increase in the consumption of fixed capital or a shock affecting their natural assets could pull their ANS shares of GNI into negative numbers. As figure 11.16 shows, Benin has consumed fixed capital and saved income at about the same rate every year, which has kept ANS share of GNI below zero in most years of the past two decades, with a slight improvement after 2016.

The Democratic Republic of Congo and Ghana are exhausting their known reserves of nonrenewable natural resources, absent major new discoveries. Nonrenewable natural resource depletion includes the consumption of oil, gas, coal, and mineral depletion. The rapid increase in depletion rates can raise concerning signs of approaching exhaustion. Over the past two decades, the Russian Federation has been reducing its nonrenewable natural resource depletion, derived from the oil price shocks of 2008 and 2014, with an increase in 2018 revealing its active oil and gas industry. Indonesia has reduced its nonrenewable natural resource depletion from almost 8 percent of GNI in 2000 to less than 3 percent in 2018 as it has transitioned toward increased production of renewable natural capital.

FIGURE 11.17 Nonrenewable Natural Capital Depletion



Source: World Bank staff calculations.
Note: See table 11A.1, in annex 11A, for definitions of the country name abbreviations used in panel b. GNI = gross national income.

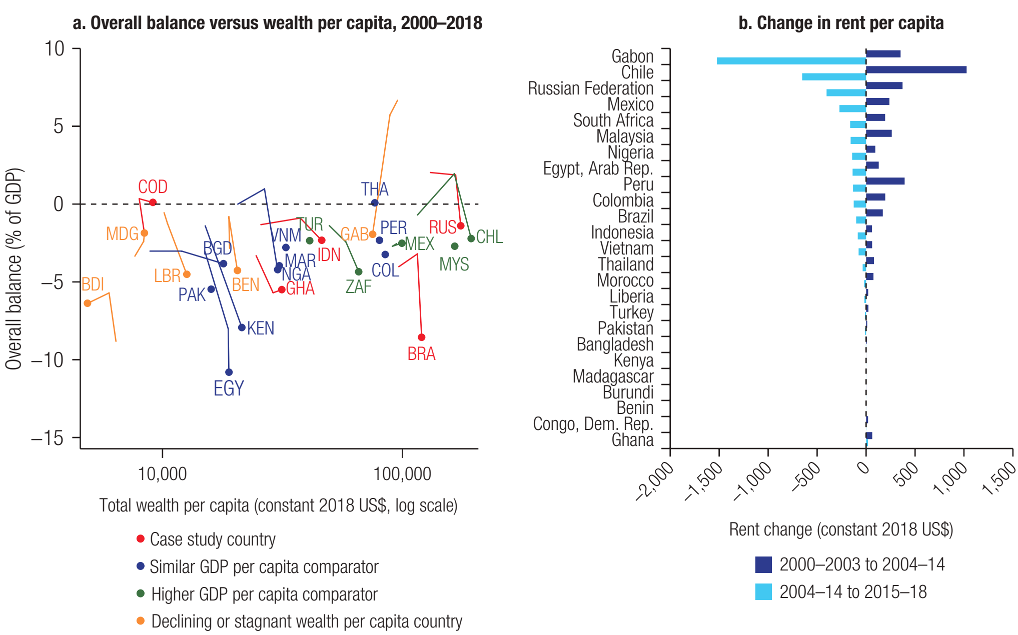
By contrast, the Democratic Republic of Congo and Ghana, which rely more on nonrenewable natural capital, have consistently increased their nonrenewable resource depletion percentage of GNI, from less than 2 percent in 1995 to more than 4 percent in 2018, putting their sustainable growth at risk (figure 11.17, panel a). Figure 11.17, panel b, shows that several fossil fuel–rich countries, including Nigeria and the Arab Republic of Egypt, are to the right of the 45-degree line, indicating that they have reduced the depletion of their nonrenewable natural capital, mainly driven by the drop in oil prices. But countries that deplete mineral natural capital or that are less fossil fuel dependent, including the Democratic Republic of Congo and Peru, appear on the left side of the 45-degree line, signaling increased depletion of their nonrenewable natural capital. These trends suggest that changes in fossil fuel wealth depletion might have been driven by cyclical forces, while mineral wealth depletion has been spared from them.

Macroeconomic and Fiscal Management

According to the IMF (2018), strong balance sheets, where governments have more assets than debt and are more resilient to shocks, can reduce borrowing costs (see Hadzi-Vaskov and Ricci [2016] and Henao-Arbelaez and Sobrinho [2017] for developing countries and Gruber and Kamin [2012] for advanced economies). Strong balance sheets can also lead to shorter and shallower recessions compared with countries that have less healthy balances (Detter and Fölster 2015). Macroeconomic instruments, such as fiscal rules, can impose a long-lasting constraint on fiscal policy that limits budgetary targets and pressures to overspend in good times, ensuring debt sustainability (Schaechter et al. 2012). There are different types of fiscal rules, including debt rules, budget balance rules, structural budget balance rules, expenditure rules, and revenue rules. Bandaogo (2020) proposes that, during times of crisis, it is important that governments include contingencies in these fiscal rules to plan how to overcome an unexpected shock to the public finances and, during good times, build up national savings that can be drawn on during times of crisis. Fluctuations in public sector net worth are subject to public sector saving and dissaving; therefore, analyzing traditional aggregate fiscal indicators and measures of public sector saving can increase understanding of the drivers of fiscal performance. The *Government Finance Statistics Manual 2014* (IMF 2014) provides helpful guidance on how to relate fiscal data to the System of National Accounts concepts and measures.

Countries with higher exposure to nonrenewable wealth per capita went into deeper deficits in their overall balances during the 2015–18 commodity bust period (figure 11.18, panel a). The overall balance, or net lending/net borrowing, is an indicator that helps to determine the extent to which governments accumulate debt. Stronger balances equipped with mechanisms to reduce the impact of fiscal risk factors could have helped

FIGURE 11.18 Overall Balance versus Total Wealth per Capita and Change in Nonrenewable Natural Capital Rent per Capita



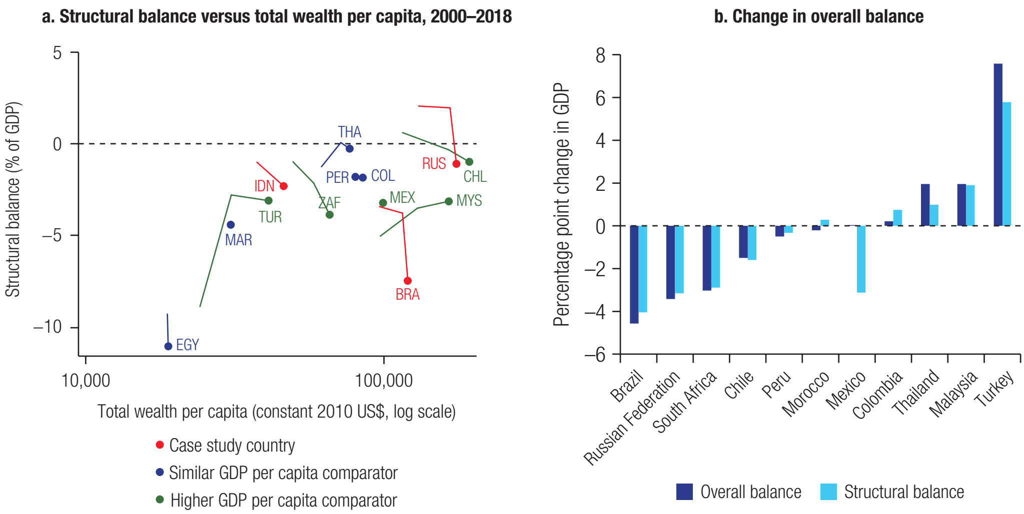
Sources: World Bank staff calculations; IMF 2020.
Note: In panel a, the lines show the trend in average values over 2000–2003, 2004–14, and 2015–18 (indicated by a dot). See table 11A.1, in annex 11A, for definitions of country name abbreviations.

countries to smooth the impact of recessions. Changes in commodity prices can affect government procurement spending, customs duty collection, and revenues (Pigato 2019). During the commodity boom, countries with higher nonrenewable natural capital per capita, such as Chile and Russia, had a significant increase of their natural resource rents derived from higher commodity prices. But as these rents dropped after 2015, the impact on the overall balance was more profound (figure 11.18, panel b). Meanwhile, countries with lower per capita nonrenewable natural capital rents, including Benin and Burundi, had little change or no impact on their overall balances after the boom years. Oil-producing countries, including Gabon and Russia, had relatively larger increases in nonrenewable natural capital rents, but after the boom ended, these rents per capita rapidly declined, having a negative impact on the countries' overall balance. Debt fiscal rules can be effective in setting public debt targets by establishing floors and ceilings in terms of GDP to ensure debt sustainability (Schaechter et al. 2012). These debt rules can be combined with expenditure rules to reduce overspending during good times and save part of the windfall revenues to create fiscal buffers during bad times.

The cyclicality of commodity prices has affected the overall balance of countries with higher shares of natural capital in total wealth. The structural balance or cyclically adjusted balance is defined as the general government cyclically adjusted balance for nonstructural elements beyond the economic cycle (percentage of potential GDP). After the most recent commodity boom of 2004–14, there was a greater impact on the overall and structural balances of countries with relatively higher shares of natural capital in total capital (figure 11.19, panel a). For example, in Russia, where nonrenewable resource rents reached 17 percent of GDP in 2018, declining fossil fuel rents contributed to an increase of more than 3 percentage points in the overall deficit (figure 11.19, panel b). By contrast, economies that have a smaller share of natural capital had little impact on their overall balances. For example, in Turkey, where nonrenewable resource rents accounted for less than 2 percent of GDP in 2018, the overall balance increased through the commodity boom period. Comparing these overall balances with the corresponding structural balances in different countries, contrasting patterns are observed (figure 11.19, panel b). For example, the percentage point change between the preboom (2000–2003) and postboom (2015–18) periods in the structural balance was similar to the change in the overall balance in countries with a higher share of natural capital. But in countries with a smaller share of natural capital, the gap between these two balances was wider. Countries with important shares of natural capital can explore the application of structural budget balance rules to enable targets that will limit increasing deficits in terms of GDP.

The commodity boom increased debt service in several countries with higher fossil fuel wealth per capita. The primary balance is defined as primary net lending (or primary net borrowing) plus net interest payable or net interest paid (interest expense minus interest revenue). In other words, the primary balance is the overall balance net of interest payments on

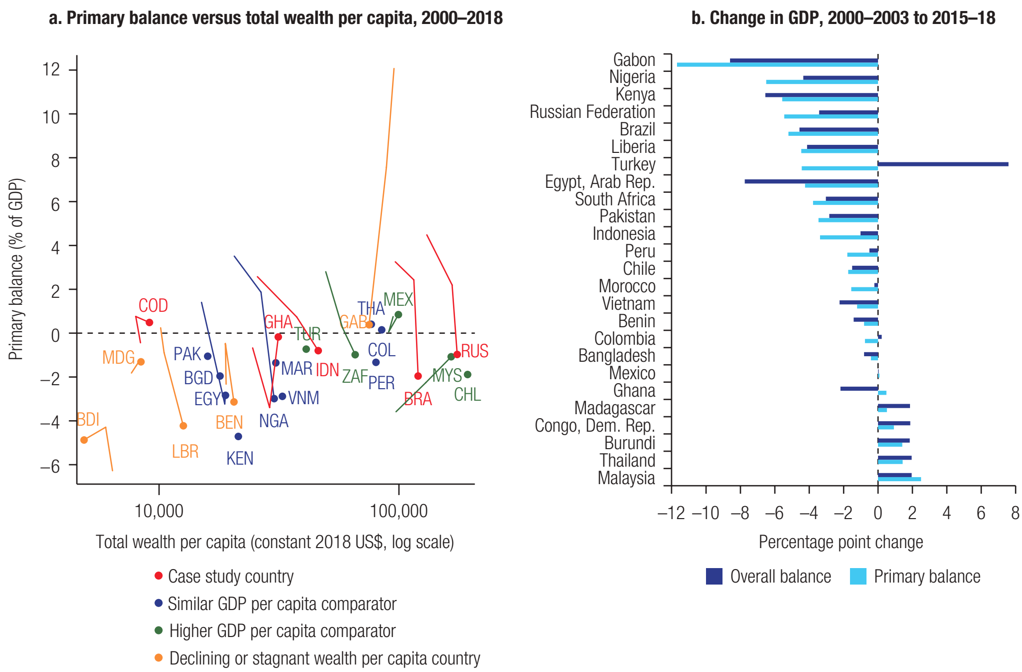
FIGURE 11.19 Structural Balance versus Total Wealth per Capita and Change in the Overall Balance as a Percentage of GDP



Sources: World Bank staff calculations; IMF 2020.
Note: In panel a, the lines show the trend in average values over 2000–2003, 2004–14, and 2015–18 (indicated by a dot). Structural balance data are not available for most countries in Sub-Saharan Africa. See table 11A.1, in annex 11A, for definitions of country name abbreviations used in panel a.

general government liabilities. Derived from the economic prosperity of the commodity boom, oil-producing countries, including Gabon and Nigeria, increased borrowing to support their lucrative oil sector. However, when the commodity boom ended and oil prices dropped, countries that depended on these oil rents experienced an impact on their public finances. This negative impact also had consequences for the net interest on that debt, increasing the deficit of the primary balance in countries including Russia and South Africa (figure 11.20, panel a). The gap between the percentage point change in the overall balance and the primary balance before and after the 2004–14 boom widened in oil-producing countries. Gabon and Nigeria were among the countries with the largest decreases in their overall balance. Not only did they have some of the largest declines in the primary balance among selected countries, but their primary balances declined by more than 2 percentage points of GDP compared with their overall balances (figure 11.20, panel b). By contrast, other countries that relied less on nonrenewable resource rents, including Bangladesh and Vietnam, had a smaller impact on their primary balances. Budget fiscal rules are useful for ensuring debt sustainability in the primary balance. Since interest payments are not directly under the control of policy makers, a budget fiscal rule can limit additional expenditure that could increase the deficit in countries that receive more rents from fossil fuel wealth and are exposed to price fluctuations.

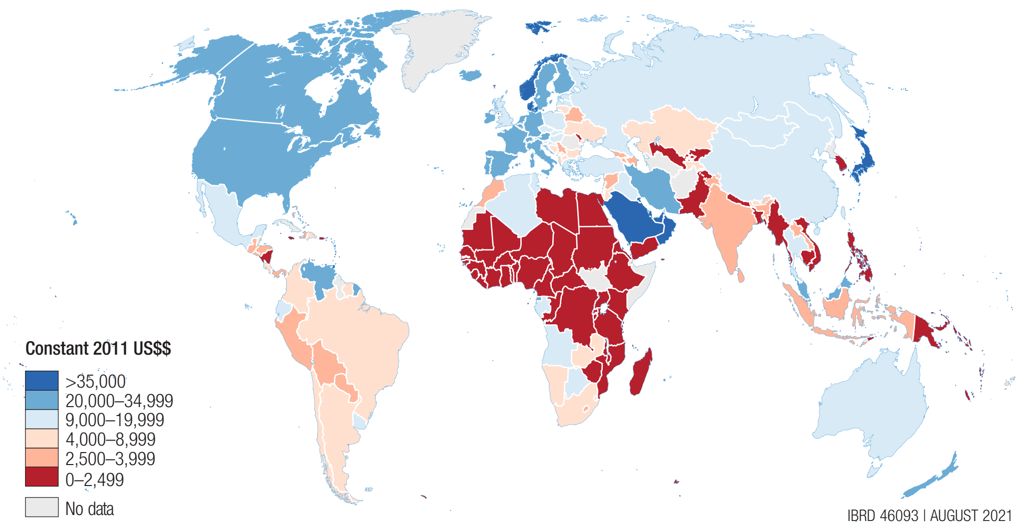
FIGURE 11.20 Primary Balance versus Total Wealth per Capita and Change in GDP



Source: World Bank staff calculations; IMF 2020.
Note: In panel a, the lines show the trend in average values over 2000–2003, 2004–14, and 2015–18 (indicated by a dot). See table 11A.1, in annex 11A, for definitions of country name abbreviations used in panel a.

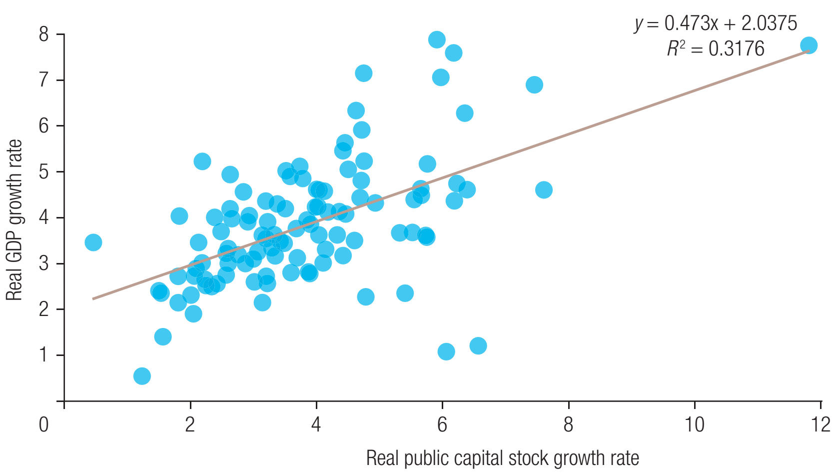
Public investment can be a catalyst for growth, but public capital stock per capita is low in several countries in the Sub-Saharan Africa, Latin America and the Caribbean, South Asia, and East Asia and Pacific regions. Public investment in capital stock is an input to produce physical assets of a country, including economic infrastructure and social infrastructure. Investments in roads, airports, public schools, and hospitals are examples of public capital stock, and they can contribute to higher productivity growth and living standards (IMF 2017b). However, as shown in map 11.1, the distribution of public capital stock is unequal, and there is an important divide between high-income countries and the rest of the world. Most high-income countries, particularly in the North America and Europe and Central Asia regions, have accumulated more than US$10,000 in public capital stock per person. By contrast, most countries in the rest of the world, principally in Sub-Saharan Africa, hold less than US$4,000 in public capital stock per capita. To reduce this gap, lower-income countries would need to increase their public capital stock with higher investment rates. According to the Investment and Capital Stock Dataset (IMF 2017a), increases in public capital stock are positively correlated with increases in GDP, meaning that investments in public capital stock are an input for economic growth (figure 11.21).

MAP 11.1 Public Capital Stock per Capita, 2011



Source: IMF 2017b.

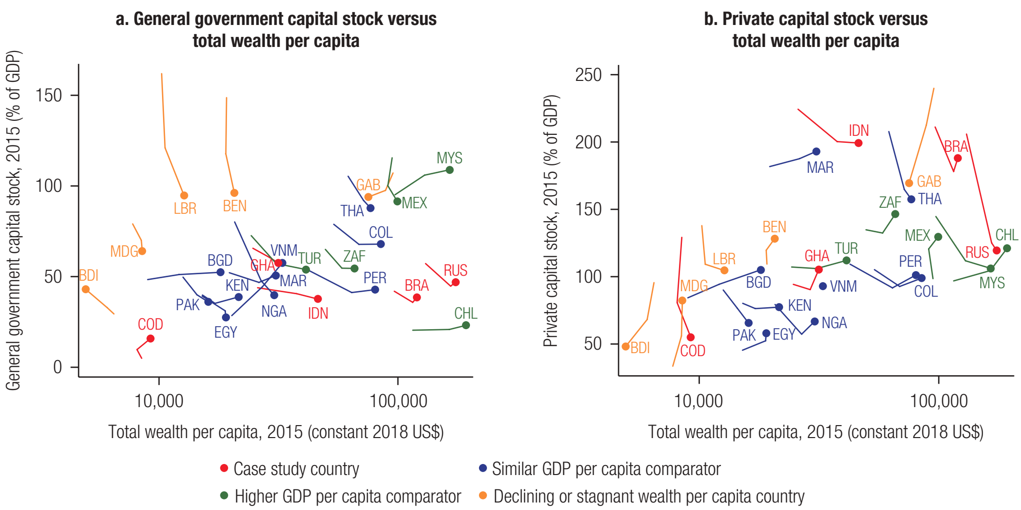
FIGURE 11.21 Long-Term Real GDP Growth versus Public Capital Growth, 1960–2015



Source: IMF 2017b.
Note: Dots represent countries. Growth rates are calculated in logs and derived as an annual average.

Countries with declining wealth per capita had a larger drop in public capital stock as a share of GDP, but an increase in private capital stock helped them maintain growth. According to the Investment and Capital Stock Dataset (IMF 2017a), most of the selected countries for this analysis had a decline in their public capital stock as a share of GDP (figure 11.22). However, countries with declining wealth per capita, like Benin, Gabon, and Liberia, had the most profound declines of this public capital stock, with a drop of more than 50 percentage points of GDP. At the same time, several countries had a decline in their private capital stock, but welcoming private investment policies helped some countries increase capital stock, including Chile, Mexico, and South Africa. Countries with declining wealth per capita that were also facing declines in public capital stock and private capital stock were more vulnerable to economic shocks. For example, Burundi, Gabon, and Liberia, countries with declining wealth per capita, saw a decline in their public and private capital stock between 2000 and 2015; after the commodity boom, they experienced negative or close to zero rates of GDP growth. By contrast, in Benin and Madagascar, also countries with declining wealth per capita, public capital stock declined but private capital stock increased during the same years. These two countries reached GDP growth rates above 4 percent in years after the commodity boom (4.9 and 6.9 percent in 2019, respectively). Therefore, investment in capital stock, public or private, could be an essential ingredient to enhance resilience after economic shocks, particularly in some countries with declining wealth per capita.

FIGURE 11.22 General Government and Private Capital Stock versus Total Wealth per Capita



Source: World Bank staff calculations using data from IMF 2017a.
Note: The Investment and Capital Stock Dataset shows data until 2015. The lines show the trend in average values over 2000–2003, 2004–14, and 2015–18 (indicated by a dot). See table 11A.1, in annex 11A, for definitions of country name abbreviations.

Institutional Capital

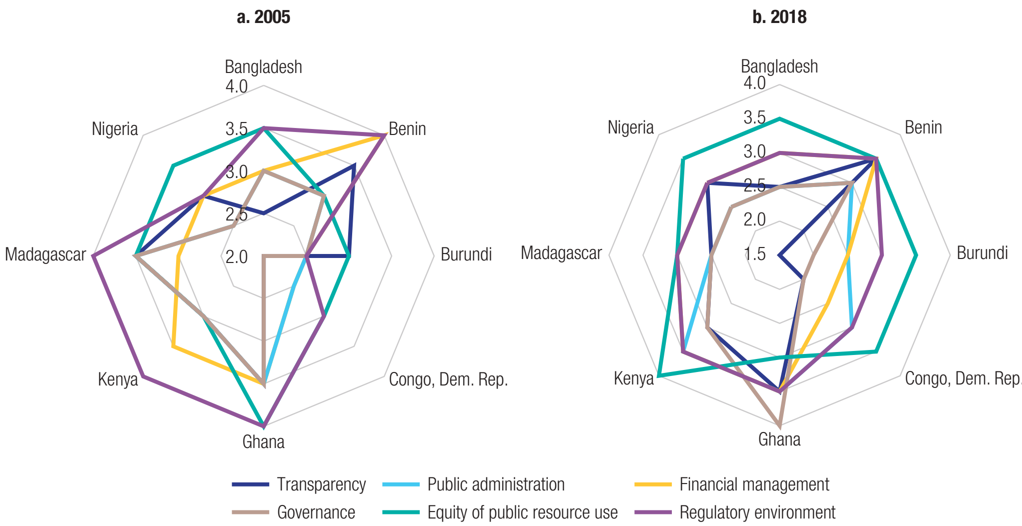
As economic diversification can be a slow process over several years, institutions become an input that can help economic policies persist over time. Resource-dependent developing countries may need even more time and can use good quality economic institutions to help them stabilize their public finances over economic cycles and guarantee that the rents from natural resources are transformed into benefits for the population. Gill et al. (2014) argue that the difference between successful developing economies and underperforming economies resides in the quality of institutions. The quality of institutions can be conceived as a characteristic of an asset, rather than an asset itself, and therefore it is not measured as part of the wealth accounts in the CWON. Chapter 15 provides a deeper discussion of this topic, covered under the broader consideration of social capital.

Transparency, property rights, rule-based governance, and regulatory environment perceptions have decreased in countries with declining wealth per capita, including Benin, Burundi, and Madagascar. One way to measure the quality of institutions is to use the dimensions of the Country Policy and Institutional Assessment scores, which capture the perception of the quality of institutions in 39 International Development Association–eligible countries (World Bank 2021). To assess the evolution of institutional capital in selected countries with different wealth per capita stock and flow, six subcomponents of this score are compared between 2005 and 2018: (1) transparency, accountability, and corruption in the public sector; (2) quality of public administration; (3) quality of budgetary and financial management; (4) property rights and rule-based governance; (5) equity of public resource use; and (6) business regulatory environment. Ratings range from 1 to 6, with higher numbers denoting better institutional performance.

There are several factors that can affect the quality of institutions, and they may depend on a country's natural resource endowment or its type of political system. Boschini, Pettersson, and Roine (2007) argue that the negative effects of bad quality institutions are larger in countries where natural resources can be more appropriable. Therefore, better institutional quality is needed in countries with natural resources that can easily be stored or transported—such as diamonds and precious minerals—than in countries where natural resources are technically or institutionally less appropriable—such as agricultural products. On the other hand, Andersen and Aslaksen (2008) found that the resource curse is more prevalent in presidential countries compared to countries run by parliaments, regardless of their democratic or autocratic classification. In line with this, a World Bank report (de la Brière et al. 2017) indicates that parliamentary systems can improve accountability and enable the creation of a legal framework to efficiently manage natural resource wealth by monitoring wealth allocation and ensuring public voices are heard.

Overall, there has been improvement in the equity of public resource use rating in all countries; however, other measures of the quality of

FIGURE 11.23 CPIA Scores, Selected Countries, 2005 and 2018

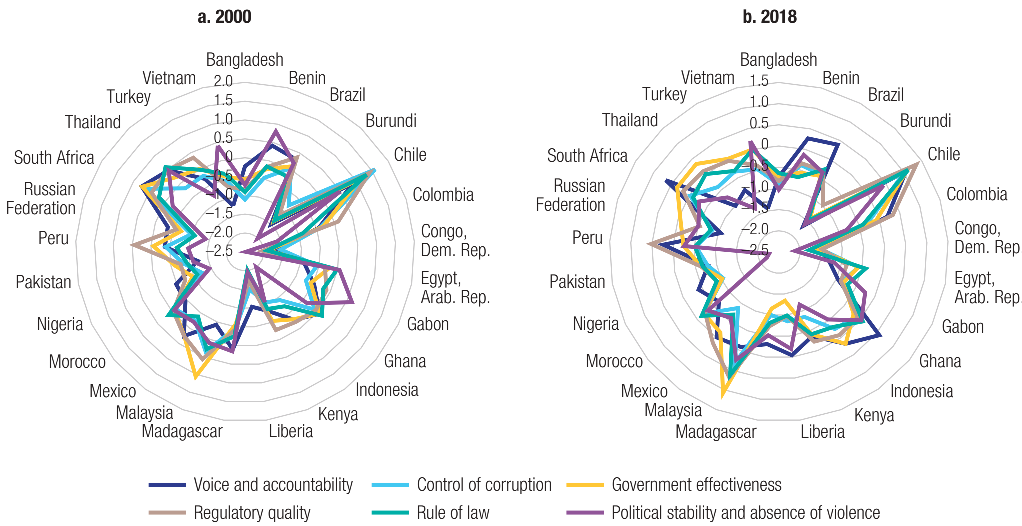


Source: World Bank staff calculations based on CPIA data in World Bank 2021.
Note: CPIA ratings range from 1 to 6. The higher the number, the better the institutional performance. CPIA = Country Policy and Institutional Assessment. Transparency = transparency, accountability, and corruption in the public sector; public administration = quality of public administration; financial management = quality of budgetary and financial management; governance = property rights and rule-based governance; public resource = equity of public resource use; and regulatory environment = business regulatory environment.

institutions have deteriorated. Countries with declining wealth per capita—Benin and Madagascar—saw a sharp reduction in their business regulatory environment from 2005 (figure 11.23, panel a) to 2018 (figure 11.23, panel b). Declines in the transparency, accountability, and corruption in the public sector ratings are another trend seen in these countries, where Burundi had the steepest decline. But in other countries where wealth per capita increased, these perceptions have improved. The rating for property rights and rule-based governance in declining wealth per capita countries was one of the highest among the comparators at the beginning of the commodity boom (figure 11.23, panel a), but after 13 years, it dropped to scores below their nondeclining wealth per capita comparators (figure 11.23, panel b). However, there have been some exceptions. The Democratic Republic of Congo is a country with declining wealth per capita, but its regulatory environment and transparency score did not drop, while the equity of public resource use substantially improved. Other countries including Ghana had a more favorable outcome. This West African country improved its rule-based governance rating above that of other countries, although the score for its regulatory environment dropped below the scores of other country comparators.

Countries with higher and rising wealth per capita are associated with better institutional quality. As displayed in figure 11.24, panel a and panel b, Chile and Malaysia, the two countries with the highest total wealth per capita among the selected countries, also have had the highest

FIGURE 11.24 WGI Scores, Selected Countries, 2000 and 2018

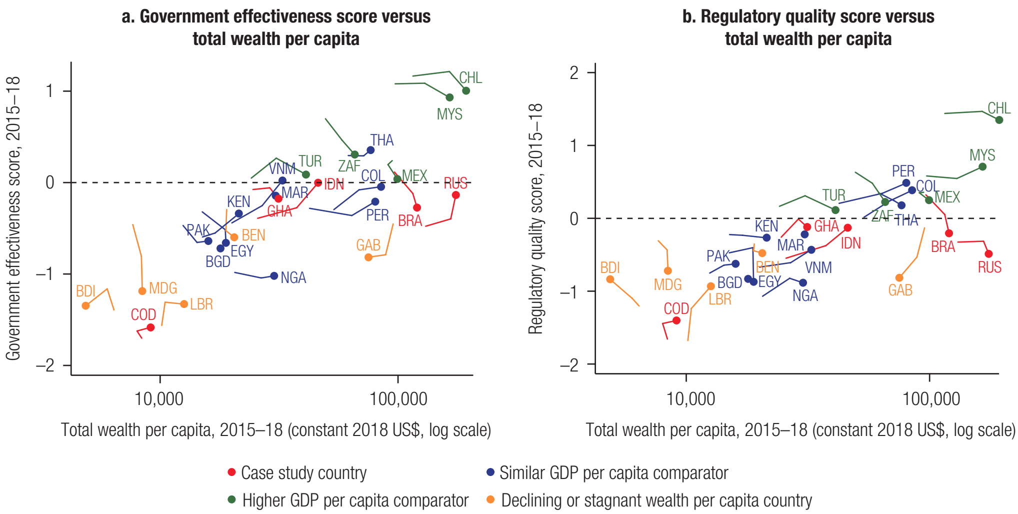


Sources: World Bank staff calculations based on Kaufmann, Kraay, and Mastruzzi 2010 and data from World Bank 2020.
Note: WGI scores range from approximately −2.5 (weak) to 2.5 (strong). WGI = Worldwide Governance Indicators.

Worldwide Governance Indicator (WGI) scores compared to the rest.[3] At the same time, in Ghana, where human capital per capita increased, the institutional quality score dimensions did not deteriorate. Indonesia is another example—it had one of the fastest increases in wealth per capita between 1995 and 2018 and the WGI scores improved. In Burundi and the Democratic Republic of Congo, where wealth per capita has been declining over the past 20 years, the WGI scores have been negative. However, there are cases of other countries with declining or stagnant wealth per capita, including Liberia, where, despite the drop in wealth, the scores improved. Another example is Gabon, where wealth per capita has been declining but the WGI scores have not deteriorated and even improved during the same years. In both cases, the strengthening of institutional quality might positively impact the long-term growth in wealth per capita.

On average, countries with higher total wealth per capita have better government effectiveness and regulatory quality scores. Government effectiveness measures the perception of the quality of public services, the degree of the government's independence from political pressures, and the quality of policy formulation and implementation. The regulatory quality score captures the perception of the government's ability to create clear policies and regulations that allow and promote the private sector's participation (Kaufmann, Kraay, and Mastruzzi 2010). Countries with higher wealth per capita among the selected countries, including Chile and Malaysia, have the highest values of these scores, while Burundi and the Democratic Republic of Congo, which have smaller per capita wealth,

FIGURE 11.25 Government Effectiveness and Regulatory Quality Scores versus Total Wealth per Capita

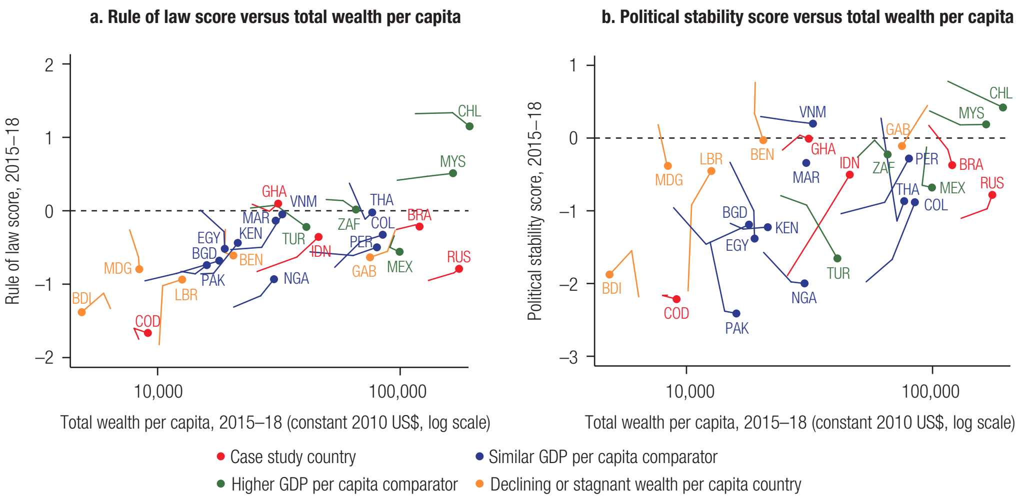


Source: World Bank staff calculations based on Kaufmann, Kraay, and Mastruzzi 2010.
Note: The lines show the trend in average values over 2000–2003, 2004–14, and 2015–18 (indicated by a dot). See table 11A.1, in annex 11A, for definitions of country name abbreviations.

have negative scores (figure 11.25). In Indonesia and in Russia, total wealth per capita has been increasing since 1995, and the perceptions of government effectiveness and regulatory quality have also improved. But in other countries, like Egypt and Brazil, although total wealth per capita has increased, perceptions of government effectiveness or regulatory quality still dropped. In other cases, even with increasing government effectiveness scores, regulatory scores are not improving, regardless of the level of wealth per capita. For example, while Russia increased its government effectiveness score, its regulatory quality score declined after the 2004–14 boom period. Therefore, it may not be sufficient for some countries to increase their wealth per capita to help them improve the perceptions of the quality of their government; they may need to spend some of the increase in wealth on their institutions.

The commodity boom helped several countries increase their wealth per capita, but this increase did not translate into better governance in all categories. The rule of law score measures the perception of the degree of contract enforcement, protection of property rights, quality of the police and courts, and likelihood of crime and violence. The political stability score captures the perception of the likelihood of political instability and/or politically motivated violence, including terrorism (Kaufmann, Kraay, and Mastruzzi 2010). The good times of wealth abundance during the commodity boom helped some natural resource–abundant economies keep or improve the perception of political stability and rule of law.

FIGURE 11.26 Rule of Law and Political Stability Scores versus Total Wealth per Capita



Source: World Bank staff calculations based on Kaufmann, Kraay, and Mastruzzi 2010.
Note: The lines show the trend in average values over 2000–2003, 2004–14, and 2015–18 (indicated by a dot). See table 11A.1, in annex 11A, for definitions of country name abbreviations.

An example is Indonesia, where wealth per capita did not stop growing between 1995 and 2018 and perceptions of rule of law and political stability also rapidly improved. But in other nonrenewable resource-dependent countries, including the Democratic Republic of Congo and Ghana, there has been little improvement in these perceptions (figure 11.26). Furthermore, in Egypt, Brazil, and Chile, where wealth has a large nonrenewable natural resource component, perceptions of the rule of law and stability deteriorated over these two decades. For countries with declining wealth per capita, excluding a few exceptions, the commodity boom was less favorable. In these countries, wealth per capita decreased, followed by a deterioration in the perception of the rule of law and political stability according to the WGI. Therefore, an increase in wealth per capita might be an ingredient to help maintain peace, but other factors might also be necessary.

Conclusion

Natural resources are a vitally important aspect of the wealth of all countries and a significant share of lower-income countries' total wealth. However, countries with nonrenewable natural resources have faced challenges in achieving diversification and sustainable development. Some countries have performed poorly in terms of achieving export diversification, but others have had success diversifying their asset portfolio.

Those experiences may prove helpful to policy makers in countries that still face very large shares of nonrenewable natural capital in their total wealth. On average, countries that have achieved higher economic growth have also seen rapid accumulation of human capital.

However, countries need to manage their natural capital portfolio rather than simply deplete or degrade it in the diversification process. Higher-income countries and those with rising wealth per capita have achieved this alongside rising natural capital values per capita. Protecting and enhancing renewable natural capital while investing in other assets could help countries achieve a more sustainable growth path.

Several countries have struggled to use their natural resource wealth to strengthen their public finances. Nonrenewable natural resources, and the associated commodity price volatility, have proven challenging for resource-dependent countries. Therefore, it is important to design mechanisms that enable countercyclical contingencies and consider rents and resource depletion in macrofiscal management. Indicators such as ANS can serve as early warning signals of unsustainable asset accumulation and natural capital depletion. Effective natural resource management also depends on strong institutions that can secure savings in good times and stabilize the economy during bad times. This institutional capital if protected and strengthened could be the ingredient that will guarantee sustained prosperity.

Annex 11A: Country Selection and Benchmarking

To compare the macroeconomic performance and evolution of wealth in different economies with distinct levels of income and capital endowments, this chapter centers the analysis on 25 countries divided into four groups: case study countries, countries with similar GDP per capita, countries with higher GDP per capita, and countries with declining or stagnant wealth per capita (table 11A.1). The first group corresponds to a selection of five countries with a large population and natural capital equivalent to at least 10 percent of the member's total wealth: Brazil, the Democratic Republic of Congo, Ghana, Indonesia, and the Russian Federation. These are referred to as "case study countries" and used as reference in several parts of the analysis. The second group of countries with GDP per capita similar to the case study countries includes Colombia and Peru in the Latin America and the Caribbean region, Nigeria and Kenya in the Sub-Saharan Africa region, Pakistan and Bangladesh in the South Asia region, the Arab Republic of Egypt and Morocco in the Middle East and North Africa region, and Thailand and Vietnam in the East Asia and Pacific region. The selection of countries was based on the following criteria: (1) being a lower-middle-income or upper-middle-income country, (2) having a population of more than 10 million people, (3) having had GDP per capita between US$1,000 and US$10,000 in 2018, and (4) having had average natural resource rents greater than zero between 1995 and 2018. The third group of higher GDP per capita comparators includes Chile and Mexico in the Latin America and the Caribbean region, South Africa in

TABLE 11A.1 Countries Selected for Analysis

Case study countries	Similar GDP per capita comparators	Higher GDP per capita comparators	Declining or stagnant wealth per capita countries
East Asia and Pacific: Indonesia (IDN)	East Asia and Pacific: Thailand (THA) and Vietnam (VNM)	East Asia and Pacific: Malaysia (MYS)	Sub-Saharan Africa: Benin (BEN), Burundi (BDI), Gabon (GAB), Liberia (LBR), and Madagascar (MDG)
Europe and Central Asia: Russian Federation (RUS)	Latin America and the Caribbean: Colombia (COL) and Peru (PER)	Europe and Central Asia: Turkey (TUR)	
Latin America and the Caribbean: Brazil (BRA)	Middle East and North Africa: Egypt, Arab Rep. (EGY) and Morocco (MAR)	Latin America and the Caribbean: Chile (CHL) and Mexico (MEX)	
Sub-Saharan Africa: Congo, Dem. Rep. (COD) and Ghana (GHA)	South Asia: Bangladesh (BGD) and Pakistan (PAK)	Sub-Saharan Africa: South Africa (ZAF)	
	Sub-Saharan Africa: Kenya (KEN) and Nigeria (NGA)		

Source: World Bank.
Note: GDP = gross domestic product.

the Sub-Saharan Africa region, Malaysia in the East Asia and Pacific region, and Turkey in the Europe and Central Asia region. The selection of the countries in this group follows the similar GDP per capita comparators criteria except that GDP per capita in countries of this group exceeds US$10,000. The fourth group of countries with declining or stagnant wealth per capita includes Burundi, Benin, Gabon, Liberia, and Madagascar. These five countries were selected from the list of 26 countries that did not significantly improve or experienced a decline of their wealth per capita between 1995 and 2018 and had declining renewable natural capital per capita (figure 11A.1).

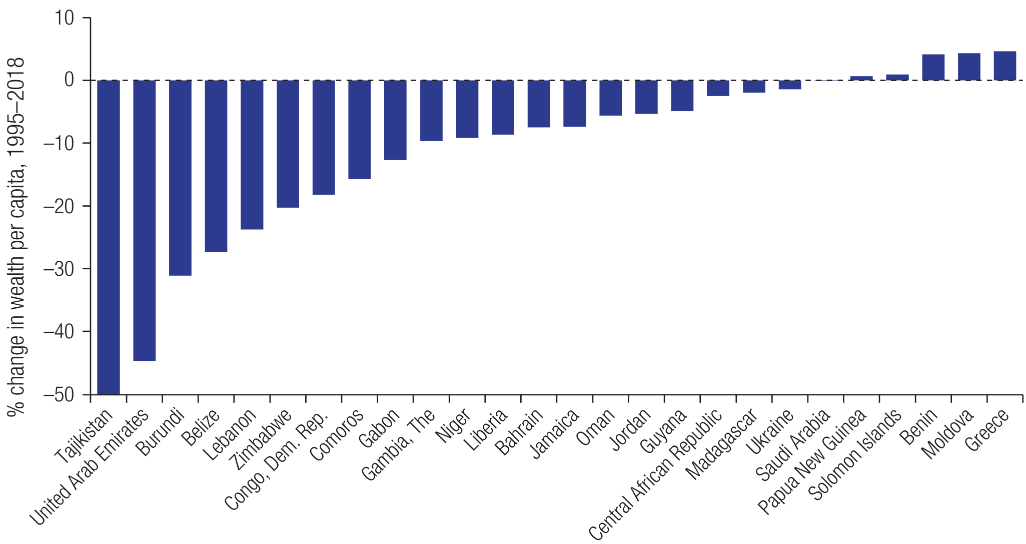
Total Wealth per Capita Growth Is Correlated with GDP per Capita Growth

Between 1995 and 2018, total wealth per capita and GDP per capita increased in the same proportion. On average, a 1 percentage point increase in total wealth per capita from 1995 to 2018 was associated with a 1.07 percentage point increase in GDP per capita (constant 2010 US$) during the same period, at 95 percent confidence level using the sample of 142 countries with no missing data for GDP and total wealth per capita (table 11A.2):

$$\Delta\ GDP\ pcap_{1995-2018} = \beta_0 + \Delta\ Wealth\ pcap_{1995-2018} + \varepsilon, \quad (11A.1)$$

where $\Delta\ GDPpcap_{1995-2018}$ corresponds to the percentage change in GDP per capita from 1995 to 2018 and $\Delta\ Wealth\ pcap_{1995-2018}$ corresponds to the percentage change in total wealth per capita for the same years.

FIGURE 11A.1 Countries Where Total Wealth per Capita Declined or Stagnated between 1995 and 2018



Source: World Bank staff calculations.

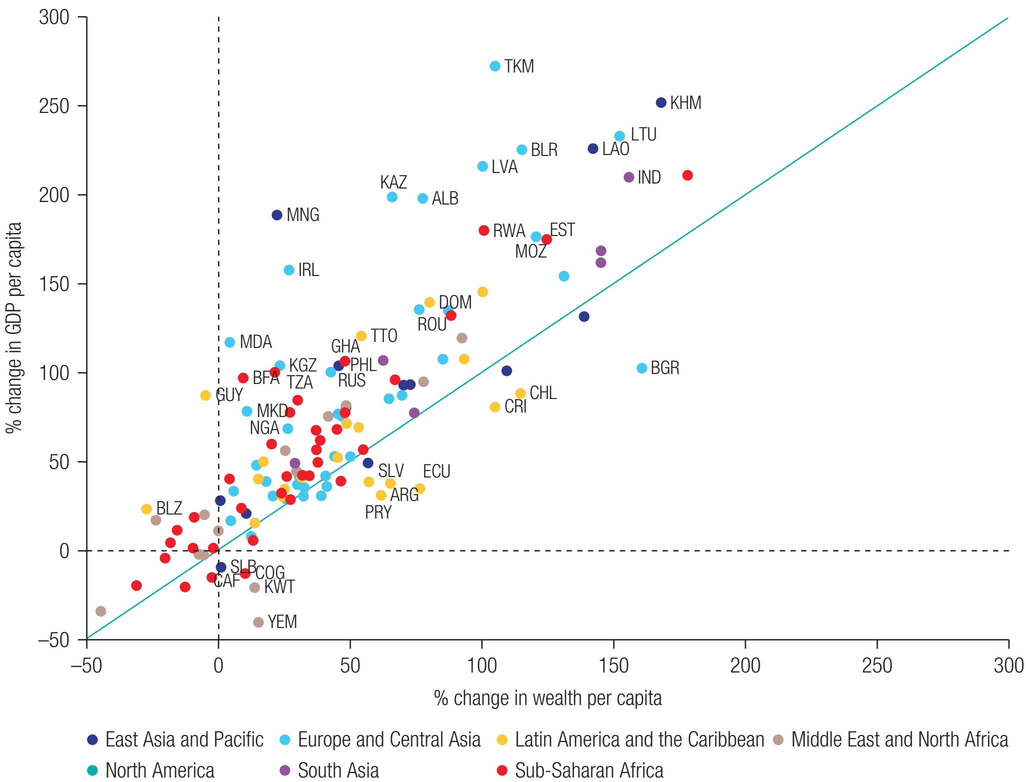
TABLE 11A.2 Correlation between Total Wealth per Capita Change and GDP per Capita Change, 1995–2018

	GDP per capita change
Total wealth per capita change	1.07*[a]
t-statistic	(5.69)
Constant	0.22[b]
t-statistic	(0.83)
N	142[c]

Source: World Bank staff calculations.
a. Correlation coefficient.
b. The y-intercept where the regression line intersects the y axis.
c. The number of countries included in the regression. The *t*-statistics are presented in parentheses
* p-value <0.001. Regression uses robust standard errors.

Therefore, the countries with the highest increase in total wealth per capita are also the countries that on average had the highest increase in GDP per capita over these 23 years. Cambodia and Lithuania are examples of this growth, where wealth and GDP per capita have increased more than 150 percent (figure 11A.2).

FIGURE 11A.2 Total Wealth and GDP per Capita Growth, 1995–2018



Source: World Bank staff calculations.
Note: Bosnia and Herzegovina, China, and Iraq are not shown, but the percentage changes in their total wealth per capita between 1995 and 2018 were 393, 406, and 420 percent, respectively.

Notes

1. The Commission on Growth and Development notes that high-growth countries have tended to invest 5–7 percent of gross domestic product per year, versus 3 percent in lower-growth countries (Commission on Growth and Development 2008).
2. Ross (2019) also finds that measuring export diversification in oil exporters could be misleading, because changes in an oil exporter's diversification index can be driven by changes in oil prices. For example, when oil prices rise, the fraction of an oil-rich country's oil exports rises, causing the country's nominal export diversity to fall.
3. An alternative to measuring the quality of institutions beyond the country coverage of the Country Policy and Institutional Assessment scores is the WGI. These indicators provide a measure of governance based on surveys and

information from experts in the public and private sectors, including nongovernmental organizations. The indicators include six dimensions: (1) voice and accountability, (2) regulatory quality, (3) political stability and absence of violence, (4) rule of law, (5) government effectiveness, and (6) control of corruption. For selected countries, these six dimensions are compared with their benchmarks. Over the past 20 years, there are contrasting outcomes for countries with different wealth endowments.

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12

Nonrenewable Natural Capital and Human Capital Distortions: Impact on Accumulation, Gender, and the Public Sector

James Cust and Pierre Mandon

Main Messages

- The average level of human capital per capita is lower in countries rich in nonrenewable natural resources—such as oil, gas and minerals—compared to those that are not.
- Evidence suggests that an abundance of these types of resources can reduce the accumulation of human capital compared to peer countries.
- The chapter identifies three ways human capital differs between these groups of countries: (1) the resource sector reallocates human capital away from some high-productivity sectors due to Dutch disease, (2) the distribution of human capital between men and women is more unequal in these (nonrenewable) resource-rich countries compared with other countries, and (3) human capital is skewed toward the public sector more in resource-rich countries.
- These characteristics may contribute to, and be associated with, lower overall worker productivity arising from resource dependence.

Introduction

The accumulation of human capital and its increasing share in total wealth is widely considered an important component of achieving sustainable development and prosperity according to the 2018 edition of *The Changing Wealth of Nations* (Lange, Wodon, and Carey 2018). As discussed in chapter 9, nonrenewable natural capital wealth forms a large share of some countries' wealth endowments: for example, 30 percent in high-income non-OECD countries. This can be as high as 65 percent of total wealth in fossil fuel–rich countries (Iraq, for example) and as high as 24 percent of total wealth in mineral-rich countries, such as Mongolia.

Converting nonrenewable natural assets into sustainable productive assets, such machines, infrastructure, and an educated, healthy population with quality jobs, is a challenging task. Nonetheless, economists identify this as an important requisite for sustainability (Hartwick 1977). Extensive research into the so-called resource curse has pointed to various ways in which nonrenewable natural resource wealth might derail sustainable development and undermine this conversion process (Sachs and Warner 2001; van der Ploeg 2011). At first glance, countries with abundant fossil fuel and/or mineral assets have, a priori, no reasons to fail in a strategy to promote the accumulation of human capital for sustainable development, thanks to economic booms and revenues generated by the production and export of resources.[1] However, the risk of mismanaging commodity booms and busts is high. It has been shown that resource wealth might generate suboptimal economic outcomes, including slower economic growth and higher inequality, especially if countries are endowed with weak political institutions (van der Ploeg 2011; Venables 2016).[2]

Monetary measures of human capital can shed light on how resource wealth might distort an economy. Using data from the new Changing Wealth of Nations (CWON) wealth accounts, this chapter observes higher levels of human capital per capita in non-resource-rich (non-RR) countries compared with resource-rich (RR) countries.[3,4] This pattern holds across all regions, with the notable exception of the Middle East and North Africa. Here RR countries have higher levels of human capital compared with other countries in the region.

There are numerous mechanisms that might undermine the process of diversification and economic development in RR countries and thus undermine human capital accumulation (de la Brière et al. 2017; Venables 2016). For instance, during the last major commodity price boom period of 2004–14, RR countries in Sub-Saharan Africa were found to become increasingly more dependent on nonrenewable natural resources, measured in terms of export concentration. Furthermore, most of them failed to use the proceeds on resource exports to invest in rapid accumulation of human and produced capital. This led to a failure to translate the boom into broad economic prosperity with an associated reduction in poverty headcount and inequality. Worse, some RR countries, particularly in Sub-Saharan Africa, have entered debt crises after the drop in commodity prices (Calderón and Zeufack 2020). The Dutch disease—a process triggered by significant resource exports—has been shown to weaken exports of other goods and services among RR countries (Harding and Venables 2016). This result is consistent with the predictions made in earlier theoretical modeling (Corden and Neary 1982).

This chapter investigates how the new CWON wealth accounts can shed light on the links between resource wealth and human capital. It adds to the evidence that RR countries are likely to be severely impacted by (1) stronger risks of traditional Dutch disease, (2) stronger distortions in the gender distribution of human capital, and (3) stronger public sector distortions.

The chapter concludes with a discussion of how countries might act to mitigate these distortions. For example, in capital-scarce RR countries, the Dutch disease might be dampened by incremental consumption skewed toward present generations and savings directed to the accumulation of domestic private and public capital rather than foreign assets, via flattening of the aggregate supply curve. Gender distortions might be mitigated by achieving higher levels of female education through various targeted measures detailed in the literature (Duflo 2012). Furthermore, policy makers can make use of new data that highlights economic distortions—such as provided by CWON 2021—to evaluate policy success or urgency. The CWON wealth accounts include variables such as the level of human capital among men and women and the percentage of human capital attributed to women. Such measures might help national authorities use macroindicators of achievements in reducing gender distortions and expanding economic opportunities for women. Public sector distortions might be mitigated by converting resource revenues into tax revenues, by transferring resource revenues directly to the citizens and taxing them in a second step, as discussed by Cust, Devarajan, and Mandon (2020).

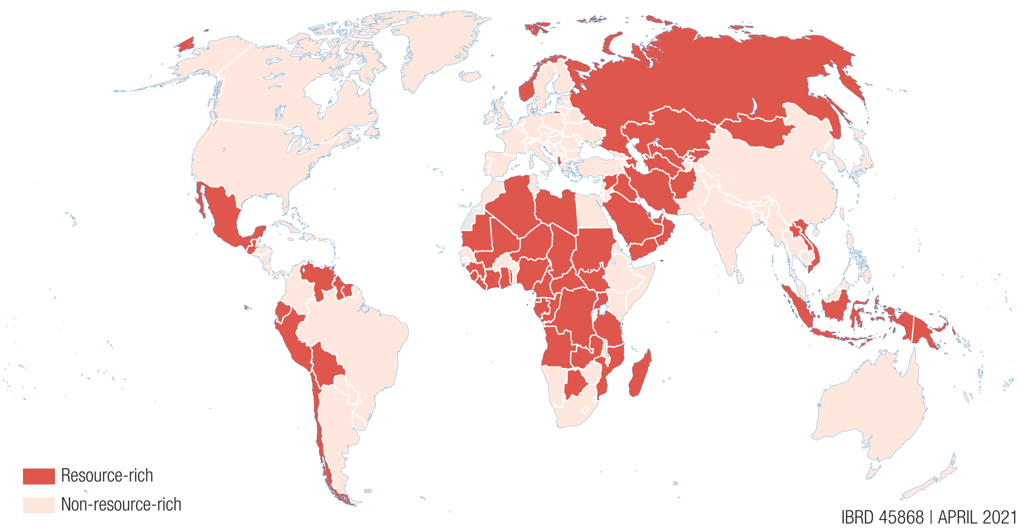
Background

Natural resource wealth is unevenly spread around the world. Regions such as the Middle East and North Africa and Sub-Saharan Africa comprise mostly resource-rich countries, while other regions have a mix of RR and non-RR economies. According to IMF (2012) and Venables (2016), 64 countries worldwide can be considered to be RR countries.

Sub-Saharan Africa is for the most part a RR region. Twenty-seven of the 48 countries in the region are defined as RR.[5] Map 12.1 shows the global distribution of RR countries. For the full list of RR countries, see table 12A.1 and table 12A.2 in annex 12A at the end of this chapter.

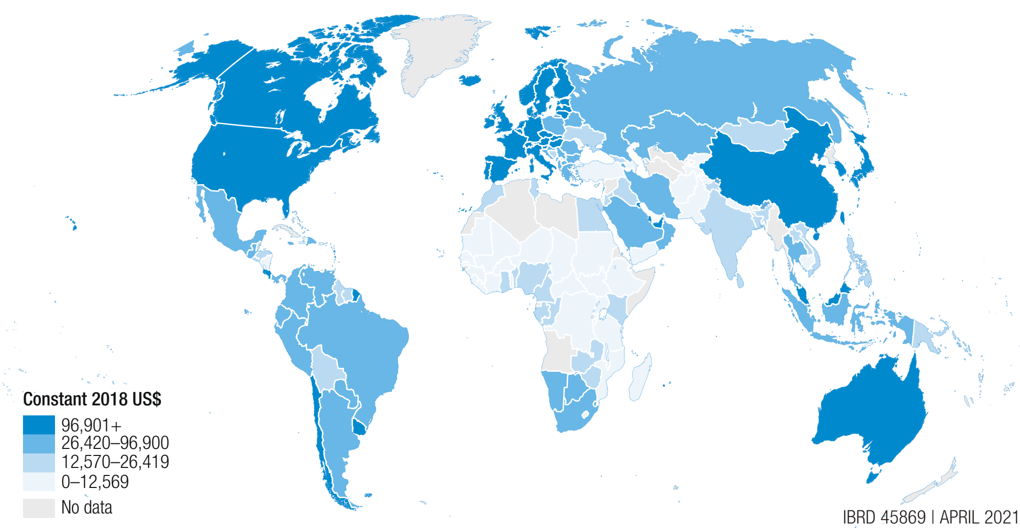
Human capital is unevenly distributed around the world. Based on the latest edition of the CWON data, map 12.2 displays the unequal distribution of human capital per capita worldwide for 2018 (the latest year available).

MAP 12.1 Worldwide Distribution of Resource-Rich Countries



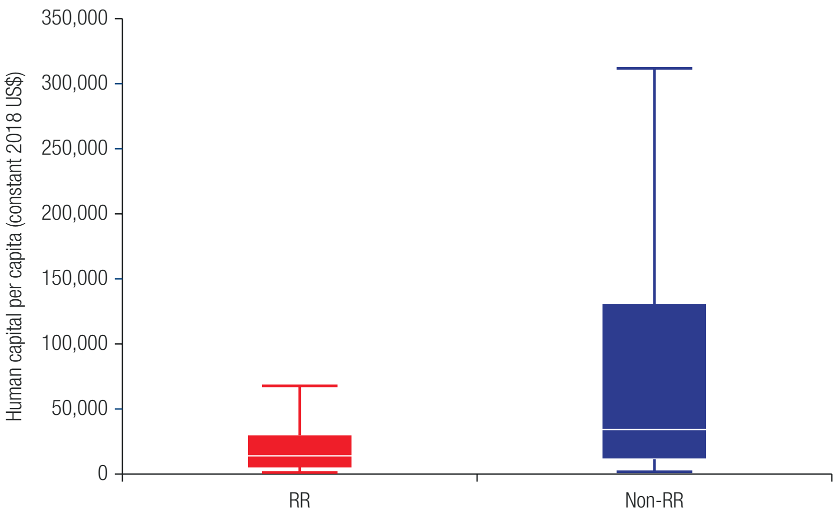
Source: World Bank.
Note: Resource-rich countries are defined as countries that derive at least 20 percent of exports or 20 percent of fiscal revenue from nonrenewable natural resources (fossil fuel assets and/or minerals and precious stones), according to IMF (2012) and Venables (2016).

MAP 12.2 Worldwide Distribution of Human Capital per Capita, 2018



Source: World Bank.
Note: The map reflects data for the most recent year available for South Sudan (2015) and the República Bolivariana de Venezuela (2014). The distribution of human capital per capita is reported per quartile of distribution of the variable.

FIGURE 12.1 Distribution of Human Capital per Capita between Resource-Rich Countries and Non-Resource-Rich Countries, 1995–2018



Source: World Bank staff calculations.
Note: The classification of resource-rich (RR) countries is from IMF (2012) and Venables (2016).

Lower levels of human capital can be found in most RR countries. In addition to the uneven distribution of human capital across the world, as shown in map 12.2, there also appears to be some degree of negative correlation between the incidence of resource dependence and lower levels of human capital per capita (figure 12.1).

Resource dependence by region shows some degree of negative correlation to human capital. Table 12.1 reports average differences in human capital per capita between RR countries and non-RR countries at the regional level[6] over 1995–2018 (over the whole period available). Higher levels of human capital per capita are observed in non-RR countries compared with RR countries within regions, with the notable exception of the Middle East and North Africa.[7,8] There may be many reasons for these cross-country differences, and this does not imply that resource dependence causes lower levels of human capital accumulation.

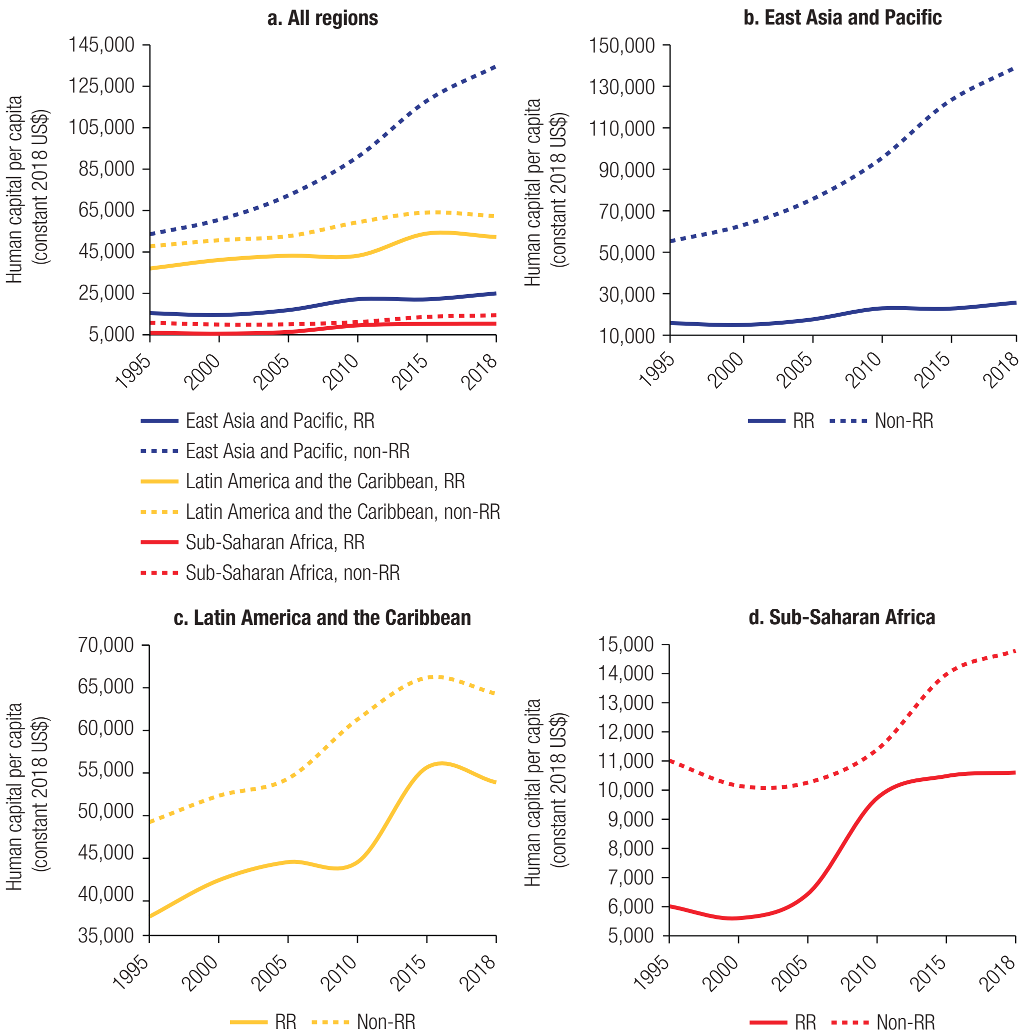
Figure 12.2 reports the evolution of human capital per capita between RR and non-RR countries over 1995–2018 in three key development regions: East Asia and Pacific, Latin America and the Caribbean, and Sub-Saharan Africa.[9] The figure highlights that human capital per capita in non-RR countries in East Asia and Pacific, Latin America and the

TABLE 12.1 Average Difference in Human Capital per Capita between Resource-Rich Countries and Non-Resource-Rich Countries, by Region, 1995–2018
constant 2018 US$

Region and resource category	1995	2000	2005	2010	2015	2018
East Asia and Pacific						
Non-RR	55,314	62,573	74,752	94,004	122,101	139,339
RR	15,841	14,886	17,376	22,803	22,733	25,718
Gap (RR – non-RR)	–39,473	–47,687	–57,376	–71,201	–99,368	–113,622
Europe and Central Asia						
Non-RR	154,732	168,111	179,369	193,521	196,107	213,411
RR	34,468	36,859	45,364	60,287	64,174	66,705
Gap (RR – non-RR)	–120,264	–131,252	–134,005	–133,234	–131,933	–146,706
Latin America and the Caribbean						
Non-RR	49,240	52,328	54,351	61,284	66,177	64,293
RR	38,156	42,427	44,556	44,552	55,656	53,897
Gap (RR – non-RR)	–11,084	–9,901	–9,795	–16,732	–10,520	–10,396
Middle East and North Africa						
Non-RR	10,423	11,873	11,904	13,736	14,055	14,727
RR	42,337	38,346	37,096	41,624	46,782	43,801
Gap (RR – non-RR)	31,915	26,473	25,192	27,889	32,727	29,073
North America						
Non-RR	480,418	551,812	546,031	552,764	593,507	621,000
RR	—	—	—	—	—	—
Gap (RR – non-RR)	—	—	—	—	—	—
South Asia						
Non-RR	6,020	7,158	8,776	10,115	12,856	15,179
RR	—	—	1,977	3,006	3,707	3,669
Gap (RR – non-RR)	—	—	–6,799	–7,109	–9,149	–11,509
Sub-Saharan Africa						
Non-RR	11,012	10,149	10,259	11,391	13,975	14,784
RR	6,012	5,603	6,437	9,728	10,481	10,603
Gap (RR – non-RR)	–5,000	–4,546	–3,822	–1,663	–3,494	–4,181

Source: World Bank staff calculations.
Note: RR = resource-rich countries; non-RR = non-resource-rich countries; — = not available. The classification of resource-rich countries is taken from IMF (2012) and Venables (2016).

FIGURE 12.2 Average Difference in Human Capital per Capita between Resource-Rich Countries and Non-Resource-Rich Countries, Selected Regions, 1995–2018

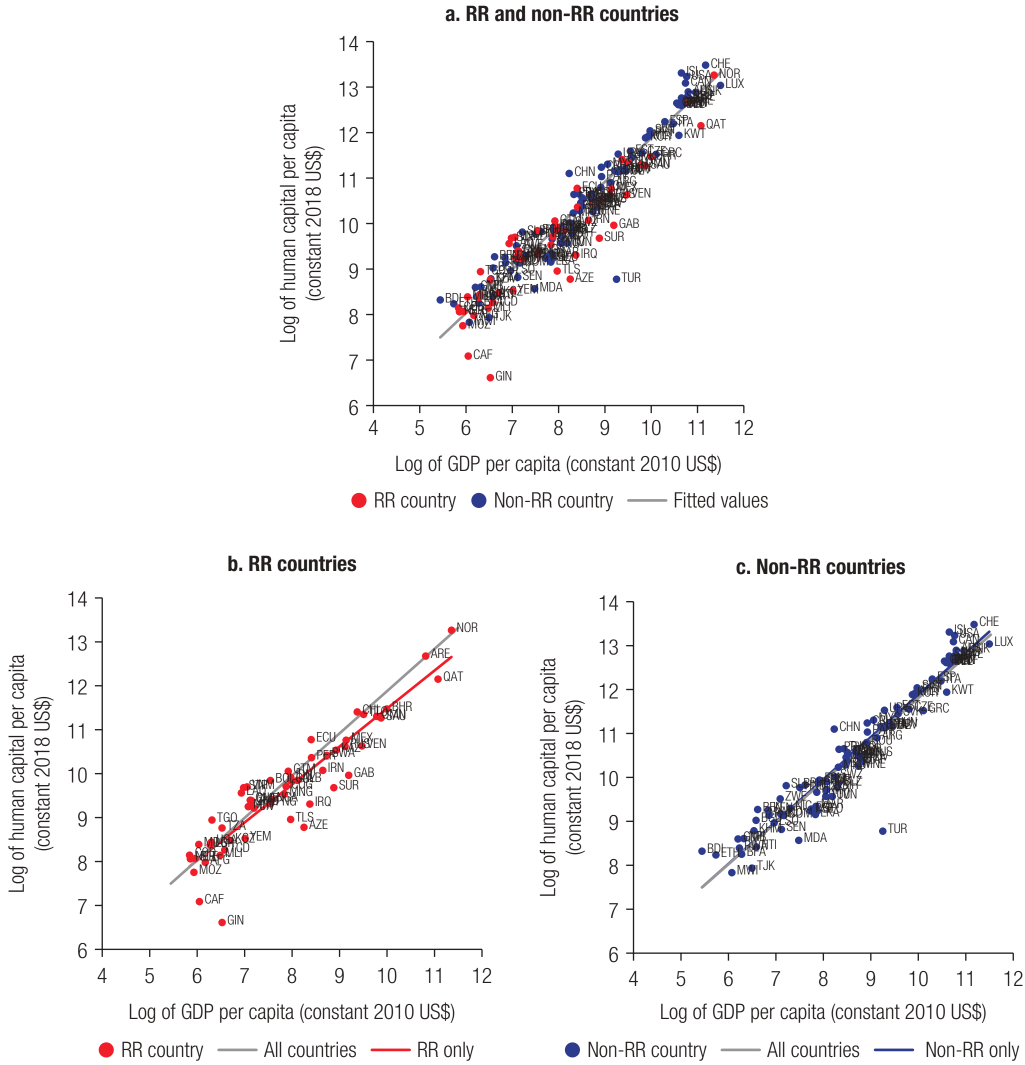


Source: World Bank staff calculations.
Note: RR = resource-rich countries; non-RR = non-resource-rich countries. The classification of resource-rich countries is from IMF (2012) and Venables (2016).

Caribbean, and Sub-Saharan Africa is not only systematically above that in RR countries, but the gap is growing over time, particularly in East Asia and Pacific, where the growing differential in favor of non-RR countries is partly due to China's rapid economic development.[10]

Human capital is strongly related to income level, but it is on average lower in RR countries across the income range. Figure 12.3 displays scatters suggesting two important

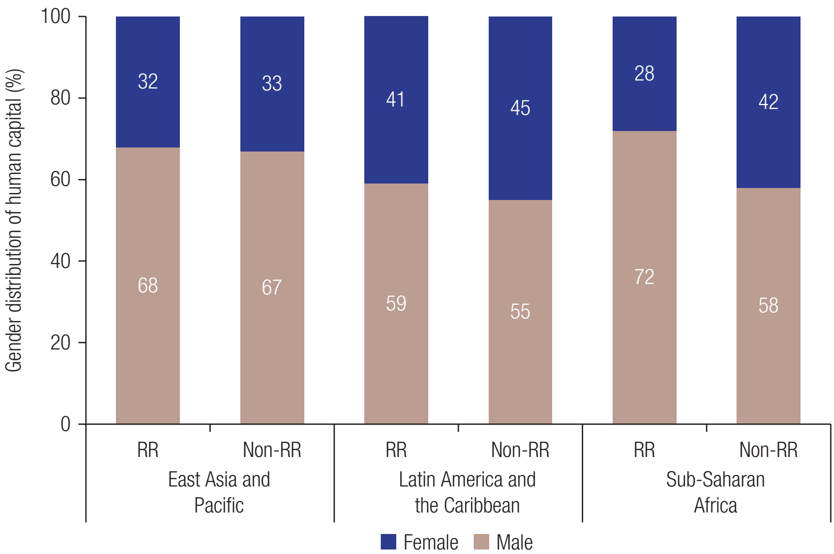
FIGURE 12.3 Correlation between Average Human Capital per Capita and Average GDP per Capita between Resource-Rich Countries and Non-Resource-Rich Countries, 1995–2018



Source: World Bank staff calculations.
Note: RR = resource-rich; non-RR = non-resource-rich. The classification of resource-rich countries is from IMF (2012) and Venables (2016).

relationships. First, there is a strong positive correlation between average income level (captured by the natural logarithm of gross domestic product [GDP] per capita) and human capital per capita (again measured using the natural log). This relationship is statistically significant at conventional levels and close to one (0.95) over 1995–2018. Second, for every level of income, non-RR countries are, on average, above RR countries

FIGURE 12.4 Average Distribution of Human Capital between Males and Females in Resource-Rich and Non-Resource-Rich Countries, Selected Regions, 2018

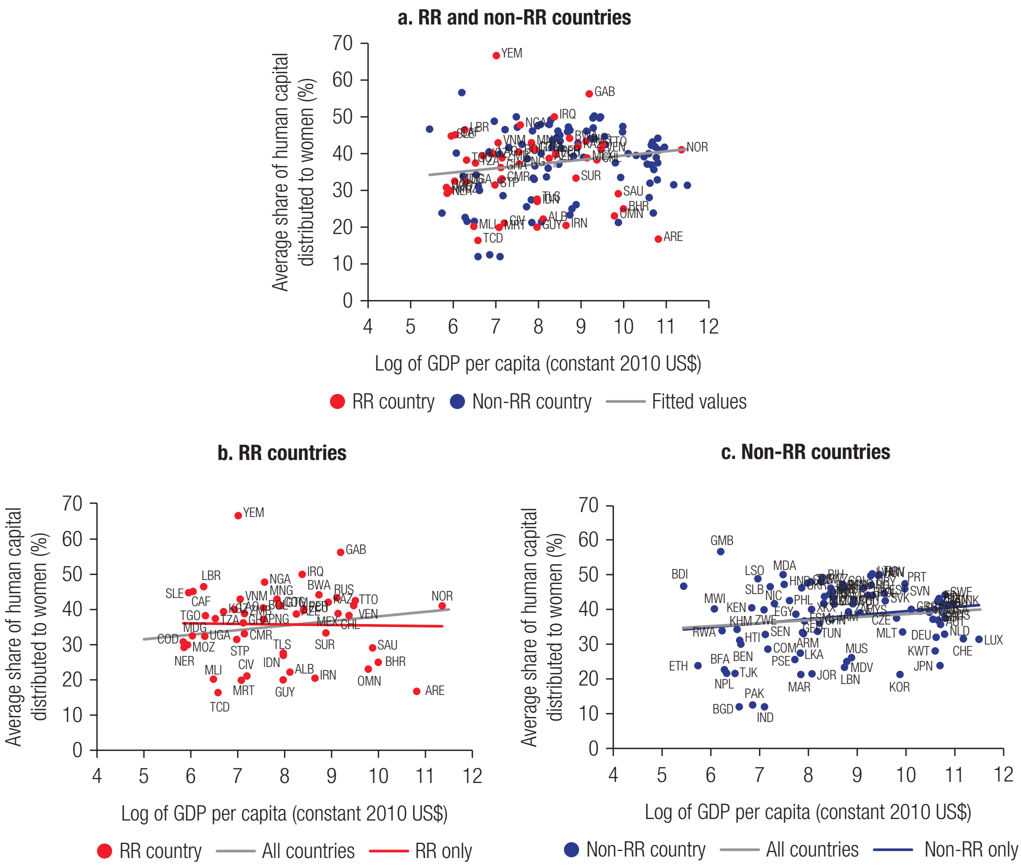


Source: World Bank staff calculations.
Note: RR = resource-rich countries; non-RR = non-resource-rich countries. The classification of resource-rich countries is from IMF (2012) and Venables (2016). A distribution closer to 50 percent between males and females means a more equal gender distribution of human capital.

in human capital terms, meaning that for a given level of economic development—measured by income—non-RR countries have a higher ratio of human capital per capita to income.

Human capital is more unequal and male-skewed in RR countries. In addition, figure 12.4 highlights that the distribution of human capital between males and females is generally relatively more equal (that is, closer to 50 percent) for non-RR countries compared with RR countries among emerging markets and developing economies, especially in Sub-Saharan Africa. For example, in 2018, 58 percent of human capital was distributed among males and 42 percent was distributed among females in non-RR countries, on average. In contrast, in RR countries 72 percent of human capital was concentrated among males and only 28 percent among females, on average. Furthermore, figure 12.5 shows a statistically positive correlation (although poorly statistically and economically significant) between the level of GDP per capita and the share of human capital distributed to women only for non-RR countries; the correlation is negative (but statistically insignificant) for RR countries. Figure 12.6 highlights a statistically positive correlation between nonrenewable natural resource rents per capita (expressed in constant 2010 US$) and the share of human capital distributed to

FIGURE 12.5 Correlation between Women's Share of Human Capital and Average GDP per Capita, 1995–2018



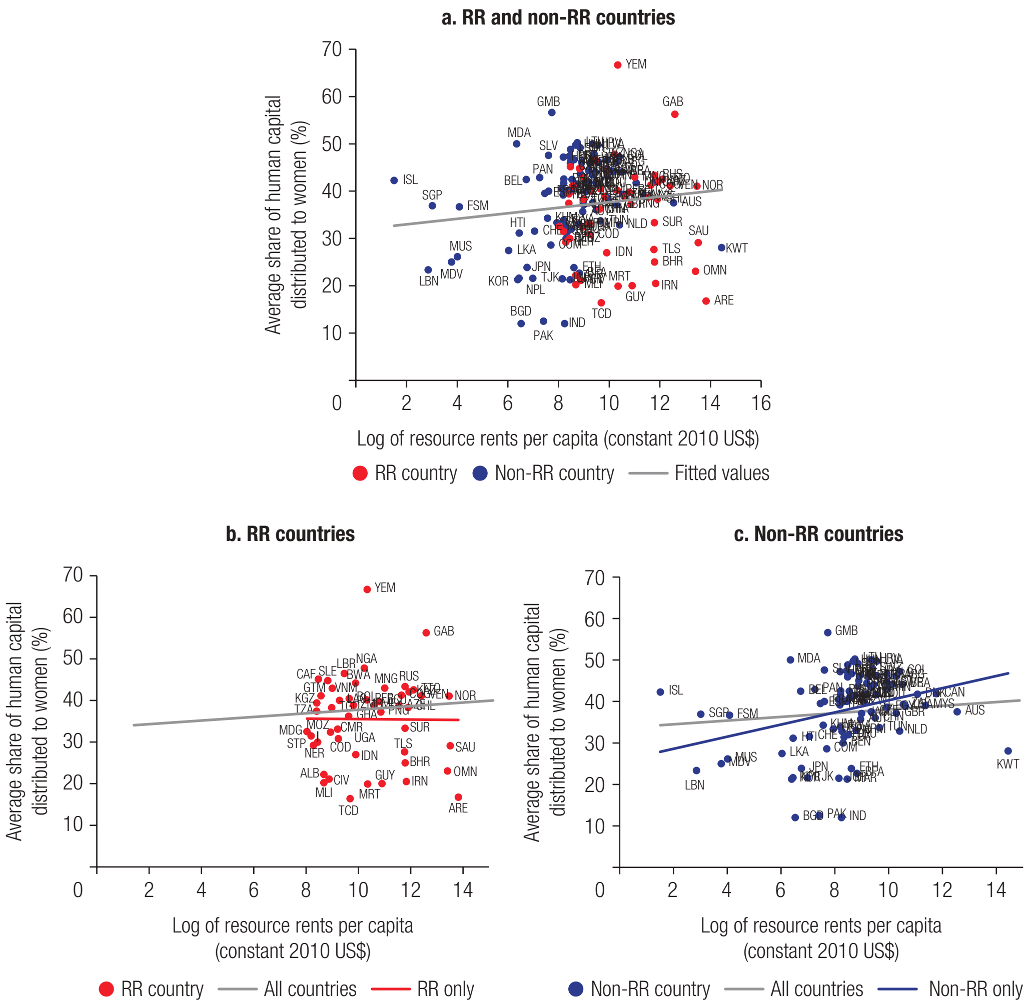
Source: World Bank staff calculations.

Note: GDP = gross domestic product; RR = resource-rich; non-RR = non-resource-rich. The classification of resource-rich countries is from IMF (2012) and Venables (2016). Women's share of human capital is measured as the amount of human capital among women over the total amount of human capital (men and women).

women only for non-RR countries; the correlation is negative (but statistically insignificant) for RR countries. In other words, the nonrenewable natural resource endowment seems to be detrimental to the distribution of human capital toward women, unless countries are above a critical threshold of nonrenewable natural resource assets in the structure of their exports and/or fiscal revenues.

Human capital is skewed toward the public sector in RR countries. Moreover, figure 12.7 illustrates the public sector distortion in RR countries compared with non-RR countries over 1995–2018. For a

FIGURE 12.6 Correlation between Women's Share of Human Capital and Average Nonrenewable Natural Resource Rents per Capita, 1995–2018

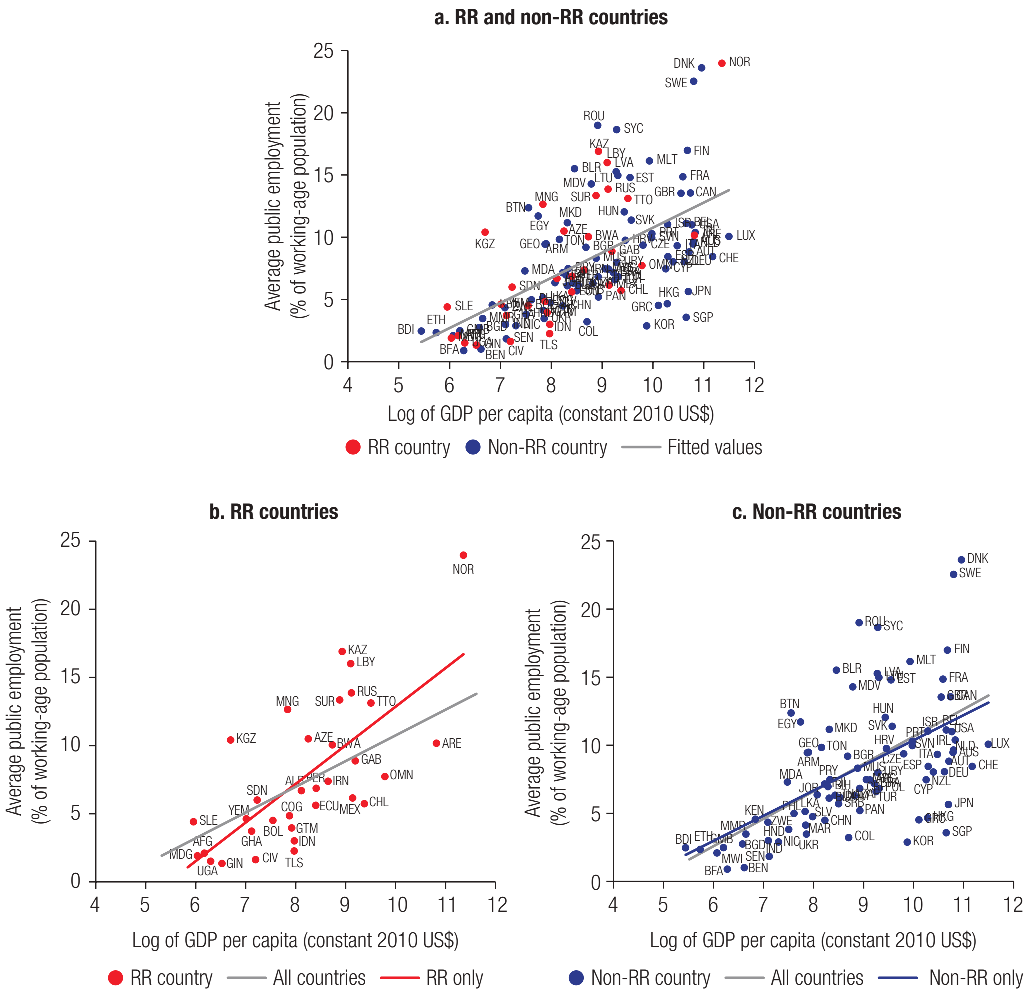


Source: World Bank staff calculations.

Note: RR = resource-rich; non-RR = non-resource-rich. The classification of resource-rich countries is from IMF (2012) and Venables (2016). The women's share of human capital is measured as the amount of human capital among women over the total amount of human capital (men and women).

given level of economic development (captured with the natural logarithm of GDP per capita), the size of the public employment (as a percentage of the working-age population, ages 15 to 64 years) is, on average, significantly higher in RR countries relative to non-RR countries.

FIGURE 12.7 Correlation between Average Public Sector Employment and Average GDP per Capita, 1995–2018



Source: World Bank staff calculations.
Note: The working-age population comprises all individuals between ages 15 and 64 years. RR = resource-rich; non-RR = non-resource-rich. The classification of resource-rich countries is from IMF (2012) and Venables (2016).

The next section discusses the possible reasons for such distortions and why these might be related to lower performance in the process of accumulation of human capital.

Natural Resource Dependence and Distortions in Human Capital Accumulation

The negative correlation between a large nonrenewable natural resource endowment and human capital is puzzling. Economic intuition suggests that more nonrenewable natural wealth should be a blessing to countries as they pursue economic growth and development. However, in line with the extensive literature investigating the *resource curse*, it has been shown that resource wealth might cause suboptimal economic outcomes. This section discusses the observed distortions in human capital value and accumulation and examines several potential mechanisms that might help explain them. The chapter presents a discussion of why RR countries might suffer from a lower level of human capital compared to their peers: (1) stronger risks of Dutch disease, (2) stronger distortions in the gender distribution of human capital, and (3) stronger public sector distortions.

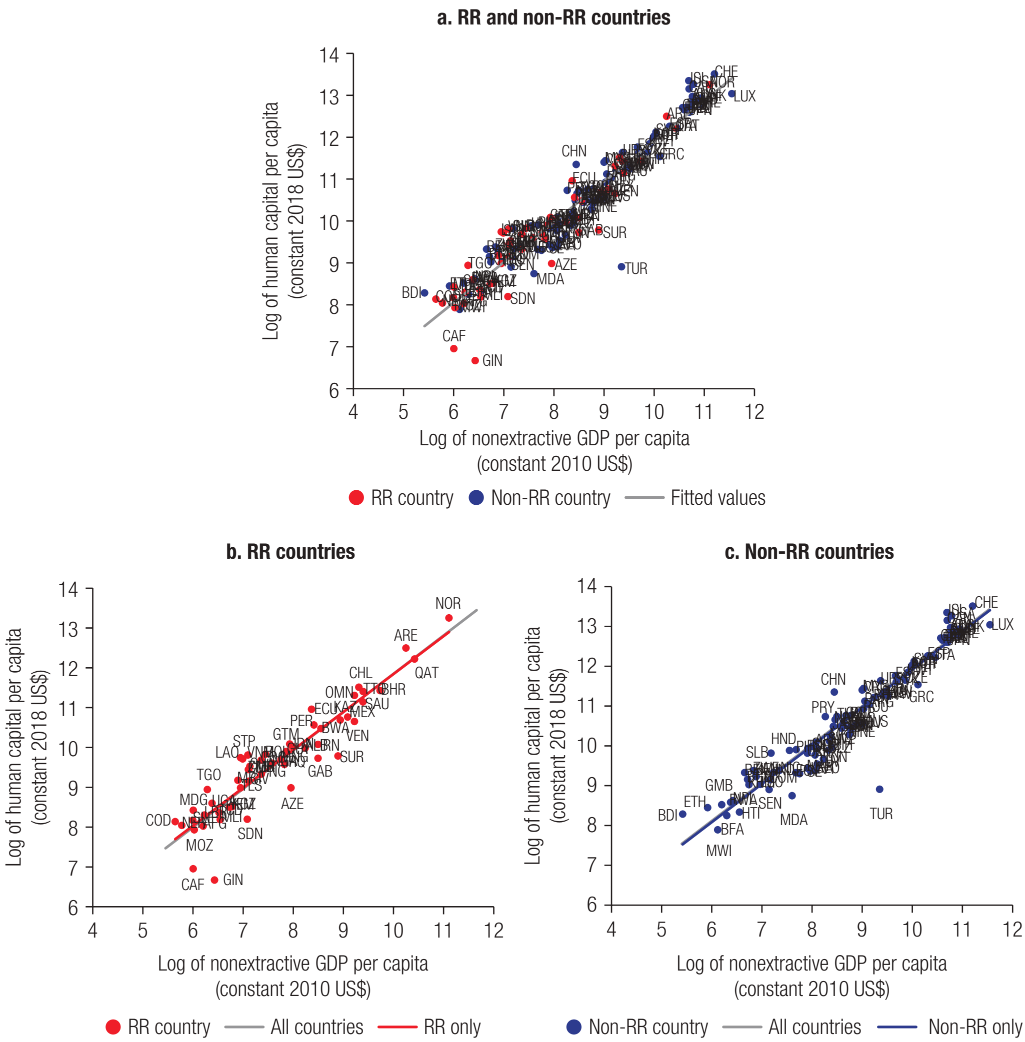
"Traditional" Dutch Disease

In line with the traditional Dutch disease hypothesis (Corden and Neary 1982), a resource boom reallocates human capital from traded sectors to the resource sector and nontraded sectors of the economy. This could distort the accumulation and value of human capital in RR countries compared to their peers. Figure 12.3 previously illustrated the link between human capital and resource wealth during the whole period studied (2004–14). It shows a more positive correlation between the level of human capital per capita and GDP per capita in non-RR countries compared with RR countries. If resource richness distorts human capital accumulation, it would be expected that these patterns would be attenuated in tests for the correlation between the level of human capital per capita and the level of *nonextractive GDP* per capita. Replacing GDP per capita with nonextractive GDP per capita allows us to compare RR countries with poorer non-RR countries but with equivalent levels of nonextractive economic activity. In other words, this removes the income and GDP components derived from resources. One hypothesis we can test is whether the extractive sector brings fewer economic opportunities relative to tradable activities, particularly manufacturing exports.

During the last commodity price boom period of 2004–14, despite large revenues for RR countries, it can still be observed, for every level of GDP, that non-RR countries are, on average, above RR countries, meaning that for a given level of economic development, non-RR countries have a higher ratio of human capital per capita. In line with the traditional Dutch disease hypothesis by Corden and Neary (1982), this may suggest that for a given level of GDP per capita, non-RR countries have larger tradable sectors with increasing returns and strong learning-by-doing effects (Frankel 2010)[11] and thus sectors offering higher economic opportunities ceteris paribus compared to RR countries.

Figure 12.8 seems to confirm that these patterns disappear when the full GDP per capita is replaced with the nonextractive GDP per capita. In other words, the comparison is of the overall GDP per capita of RR countries with poorer non-RR countries, but with a similar level of nonextractive GDP. In line with the Dutch disease hypothesis, extra dollars in extractive activities do not seem to convert into higher levels of human capital per capita for a given level of economic development.

FIGURE 12.8 Correlation between Average Human Capital per Capita and Average Nonextractive GDP per Capita, 2004–14



Source: World Bank staff calculations.
Note: RR = resource-rich; non-RR = non-resource-rich. The classification of resource-rich countries is from IMF (2012) and Venables (2016).

Gender Distortions

Beyond the traditional Dutch disease, Ross (2008) describes several theoretical reasons why fossil fuel production is detrimental to gender equality through a lack of opportunities for women, which explains the preliminary insights from figure 12.3: the arguments hold for extractive industries in minerals and precious stones. Traditional models of the Dutch disease do not consider whether the changes in the economy away from the traded sectors (agriculture and manufacturing) affect men and women differently (Frederiksen 2007). Once the model is extended to capture the conditions that women face in most RR countries, it can be seen how a boom in extractives might squeeze women out of the labor force and, by extension, potentially larger civic responsibilities, as suggested by Ross. This might also lead to human capital values becoming more skewed toward men in RR countries.

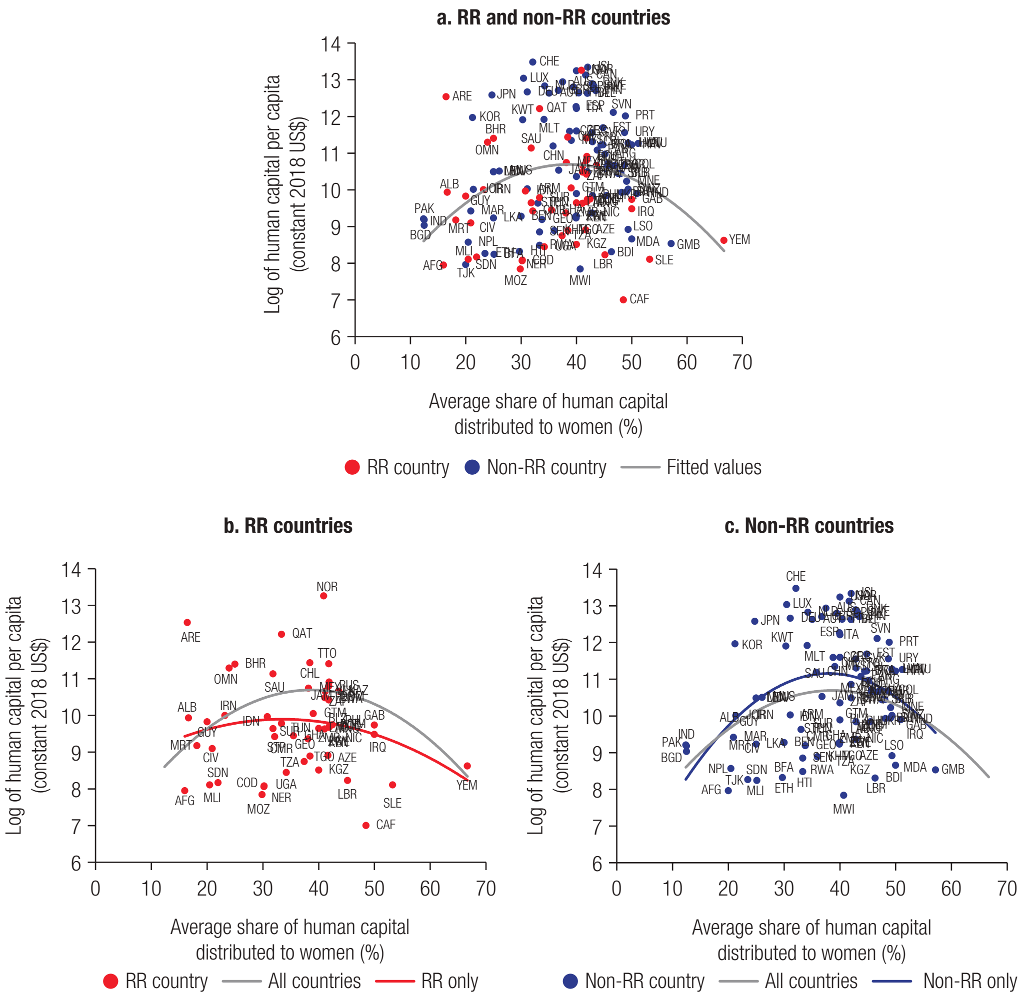
A lower median percentage share of human capital is found to be distributed to women in RR countries (about 36 percent distributed to women over 49 countries) relative to non-RR countries (about 38 percent distributed to women over 90 countries) over 2004–14. Figure 12.9 reports the correlation between the natural logarithm of per capita human capital (in US$) and the share of human capital distributed to women over 2004–14. As expected, there is a positive and statistically significant correlation between the share of human capital distributed to women and the level of human capital per capita: higher human capital for women leads to higher human capital in general. The nonmonotonic relationship suggests a reverse of the correlation when the share of human capital distributed to women exceeds 50 percent (when women have more human capital than men on average); the optimal point is reached when the share of human capital is distributed almost equally between men and women. But, as for the correlation between human capital and income level per capita, there is a stronger positive correlation between the share of human capital distributed to women and the level of human capital per capita in non-RR countries relative to RR countries. In line with Ross (2008), for a given percentage of human capital distributed to women, women have lower wage gaps relative to men, higher participation in the labor market (due to more buoying tradable sectors of activity), and/or stronger involvement in civic and political life, enabling them to have better economic opportunities in non-RR countries relative to RR countries.

Public Sector Distortions

In line with figure 12.7, Stefanski (2015) finds that RR countries tend to employ a larger proportion of workers in the public sector than other countries. This may be driven by different incentives for government to create jobs out of government revenues, which are likely to be stronger in RR countries where a large fraction of revenues come from resource sector taxation. This implicit misallocation of resources has large, detrimental impacts: a 10 percentage point increase in revenues is associated with about 2 percent lower aggregate productivity and about 1 percent lower welfare. Additionally, Balde and Cust (2020) find that additional resource revenues increase the employment share of the public sector in total employment. Relatedly, the resource exports are associated with an increase of public wage bills as a share of the growing economy and as a share of total government expenditures.

Figure 12.10 reports the correlation between the natural logarithm of human capital per capita and public employment[12] during the commodity boom price period, 2004–14.

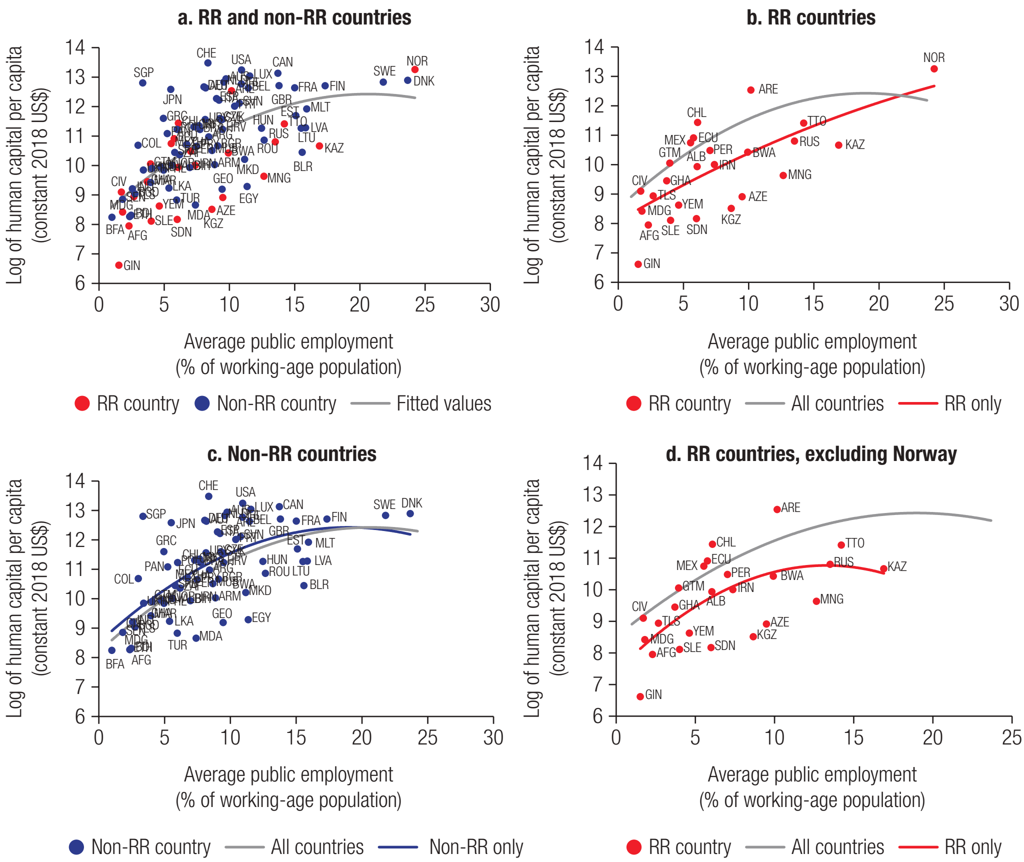
FIGURE 12.9 Correlation between Average Human Capital per Capita and Share of Human Capital for Women, 2004–14



Source: World Bank staff calculations.
Note: RR = resource-rich; non-RR = non-resource-rich. The classification of resource-rich countries is from IMF (2012) and Venables (2016).

A nonmonotonic relationship is found between the size of the public sector, captured by the ratio of public employment over the working-age population, and the level of human capital per capita over 2004–14. This suggests the existence of a statistically significant and positive, although diminishing, correlation between the size of the public sector and the level of human capital per capita. A correlation is also observed between the size of the public sector and the level of human capital per capita,

FIGURE 12.10 Correlation between Human Capital per Capita and Public Employment in the Working-Age Population, 2004–14



Source: World Bank staff calculations.

Note: RR = resource-rich; non-RR = non-resource-rich. The classification of resource-rich countries is from IMF (2012) and Venables (2016).

which is more strongly positive for non-RR countries compared with RR countries (figure 12.10, panel a). The exceptions are three Scandinavian countries, Denmark, Norway, and Sweden, which are characterized by large public sectors and high values of human capital. These three countries are considered to have among the best administrative practices worldwide, as reflected by their government effectiveness scores of 1.94 for Denmark, 1.86 for Norway, and 1.83 for Sweden for 2018. The median value of the government effectiveness score for high-income countries is around 1.30 (higher values mean better government effectiveness).[13] In the present case, Norway seems to perform slightly better than Denmark and Sweden on that combination of large public employment over the working-age population and high values of human capital per capita. Accordingly, it is not surprising that Norway clearly appears to be an outlier among RR countries (figure 12.10, panel b). When Norway is removed from the sample of RR countries, a much weaker positive nonmonotonic correlation is found between the size of the public sector and the level of human capital per capita over 2004–14 compared with non-RR countries (figure 12.10, panel d). In line with Stefanski (2015), and with the notable exception of Norway, these findings suggest that revenues from extractive resources would contribute to finance-inefficient administrations and bureaucracies, especially in RR countries where the public sector is generally larger than in non-RR countries for a given level of economic development (figure 12.7).

Policies to Mitigate Human Capital Distortions Arising from Nonrenewable Natural Resource Wealth

The previous section highlighted three potential distortions in RR countries that potentially undermine the level and accumulation of human capital: distortions in the form of (1) Dutch disease, (2) inequalities in the distribution of human capital between men and women, and (3) the public sector. This section proposes policy pathways to enhance the accumulation of human capital in RR countries. It considers how the CWON wealth accounts might help guide policy makers.

How to Mitigate the Dutch Disease

As emphasized in chapter 11, improving institutional quality may be an important pathway to facilitate greater economic diversification. However, additional actions by government may be required to mitigate risks of Dutch disease during the period of resource dependence. The underlying question when studying the Dutch disease is how an appreciation of the real exchange rate from resource revenues might be managed and mitigated by the government. The conventional permanent income hypothesis is that a sustained increase in consumption can be supported by interest on accumulated foreign assets through foreign exchange reserves or a sovereign wealth fund, as recommended by the International Monetary Fund,[14] or the more restrictive formulation of this approach called the bird-in-hand strategy (Barnett and Ossowski 2003).[15] These approaches side-step the issue of a loss of domestic competitiveness caused by Dutch disease. However, as analyzed by van der Ploeg and Venables (2011), these approaches are not optimal for all RR countries and especially for lower-income RR countries, which are generally capital-scarce.[16] According to van der Ploeg and Venables (2011), capital scarcity implies a low capital-labor ratio, little public infrastructure, low wages and income, and a high domestic interest rate. As only 9 of the 64 RR countries in our analysis are high-income economies,[17] the case of capital-scarce RR countries is considered as the reference.

In capital-scarce RR countries, a temporary influx of foreign exchange, consecutive to a commodity price boom, a massive resource discovery, or increasing resource production, should typically be spent and invested domestically, not spent to accumulate foreign assets. This allows for incremental increases in consumption for present generations as well as the use of savings for a combination of foreign debt reduction and the accumulation of domestic capital. First, it is argued, consumption should be skewed toward the present generation, because of the relative poverty of the present generation compared with those in the far future. Second, savings should take the form of a domestic capital accumulation to compensate for relative capital scarcity. This use of public spending is expected to boost private investment and accelerate growth of the nonresource sectors through (1) improving public infrastructure and the provision of public services such as electricity or internet (domestic public investment), (2) lower interest rates (foreign debt reduction), and (3) via a process of "investing in investing." This is where capital-scarce RR countries can use public investment and related policies strategically to raise the overall absorptive capacity of the economy, by flattening supply curves, and thus mitigate Dutch disease effects on the nontraded sectors.

How to Mitigate Gender Distortions

Fortunately, most actions to mitigate the traditional Dutch disease can also help dampen gender distortions in the distribution and the accumulation of human capital. As is noted by Anker (1997), labor markets are typically segmented by gender: men work in some occupations and women in others, even when their qualifications are similar (see box 12.1). Mitigating the Dutch disease could help to reduce imbalances in strongly segmented labor markets and rebalance economic opportunities and even civic responsibilities to women.[18]

Implementing measures for achieving higher levels of female education can also help mitigate gender distortions in RR countries. For example, de la Brière et al. (2017) highlight that gender inequalities are abnormally large in RR countries. Focusing on the Sub-Saharan Africa region, they find that the average difference between boys and girls in school participation of children ages 6–14 years is 21 percentage points in non-RR Sub-Saharan Africa countries, compared with 31 percentage points in fossil-fuel-rich Sub-Saharan Africa countries and 26 percentage points in mineral-rich Sub-Saharan Africa countries. The differences are starker for grade 6 completion (access to junior high schools and secondary schooling) because gender gaps tend to widen at higher levels of schooling. For example, the male-female gap is 33 percentage points in non-RR Sub-Saharan Africa countries but 47 percentage points in fossil-fuel-rich Sub-Saharan Africa countries. In an extensive literature review, Duflo (2012) summarizes the main effective factors that can lead to women achieving higher levels of schooling. These factors include (1) compulsory junior secondary schooling, (2) deworming programs, (3) quotas of women in local committees or school committees

BOX 12.1 Illustrative Case of the Republic of Korea: How Structural Transformation Was Ultimately Beneficial for Women in the Context of a Highly Segmented Labor Market

As detailed by Ross (2008), the case of the Republic of Korea illustrates how export-oriented manufacturing (a booming traded sector) can draw women into the labor force and boost their civic commitment. When Korea industrialized in the 1960s, women began to take jobs in factories that produced goods for export.[a] Their low wages[b] made them attractive to employers and helped fuel Korea's economic boom: by 1975, female-dominated industries produced 70 percent of the country's export earnings. The growth of the export sector, in turn, boosted the female share of the labor force, which rose by 50 percent between 1960 and 1980.

In 1987, female activists took advantage of Korea's democratic opening to establish the Korean Women's Associations United. Unlike earlier women's organizations, it worked for improved labor conditions and women's rights and took a more confrontational stance toward the government. More traditional women's groups also began to focus on women's rights. In the mid-1990s, women's organizations started to push for greater female representation at all levels of government: the number of female representatives in the national assembly rose from 8 in 1992–96 to 16 in 2000–2004; female membership on policy-setting government committees increased from 8.5 percent in 1996 to 17.6 percent in 2001; and the percentage of female judges rose from 3.9 percent in 1985 to 8.5 percent in 2001.

The lobbying strength of the women's movement, and the growing number of women in government, has led to a series of political reforms. These included the Gender Equality Employment Act (1987), revisions to the family laws (1989), the Mother-Child Welfare Act (1989), the Framework Act on Women's Development (1995), and a bill stipulating that political parties must set aside for women at least 30 percent of their national constituency seats (2000).

a. Leading sectors at the time were dishware, electronic goods, shoes, textiles, and garments.
b. About half of male wages at the time.

(for example, business process outsourcing centers in India), and (4) the change of perceptions of parents on the returns to education. Duflo, however, points to the costs of specific measures targeting women, such as scholarships for girls or the availability of latrines in schools, which can ultimately be detrimental for boys' access to school, especially in countries with high fiscal constraints.

Targeting the CWON wealth account variables could be a useful yardstick for policy makers. This would include the level of human capital among men and women and the percentage of human capital distributed to women. Such measures could help national authorities to establish macroindicators of achievements in reducing gender distortions and promoting more equitable distribution of human capital wealth.

How to Mitigate Public Sector Distortions

The previous section explained that RR countries have higher public sectors due, all things being equal, to political economic issues (Stefanski 2015). More precisely, Cust, Devarajan, and Mandon (2020) underline two fiscal characteristics specific to RR countries. First, citizens in those countries generally lack information about the extent of resource revenues, the services available to them, their rights, and the quality and standard of services they should expect. For instance, two-thirds of the population in Tanzania reported that they would like more information about natural gas discoveries (de la Brière et al. 2017). Second, and more fundamentally, citizens in these countries may not have as much of an ability and incentive to scrutinize how the government spends resource revenues, relative to other forms of revenue generation such as income tax. In sum, nonrenewable natural resource revenues may lead to public expenditures, for which governments are not held as accountable compared with tax revenues, and the lack of accountability might lead to worse outcomes and worse socioeconomic opportunities for the population.[19]

One way to tackle the problem might be to convert resource revenues into both cash transfers for citizens and ultimately increased tax revenues for government. This would be achieved by transferring resource revenues directly to the citizens and then government taxing back some portion of these revenues. This could be done through direct cash transfers, so that citizens can spend them, and the government taxing back a portion in a second step to finance public expenditures (Cust, Devarajan, and Mandon 2020).

If successful, this mechanism could give citizens a greater stake in the government revenues originally derived from resources. This may encourage them to scrutinize the management of the sector, as well as the eventual spending of government revenues. The intuition, based on Devarajan et al. (2013), is as follows: citizens face a trade-off between spending money on private goods and scrutinizing public expenditures. The latter, if effective, could lead to more public goods. If citizens are uncertain about the extent of public revenues, they are less likely to invest time and money in scrutinizing public spending because the benefits are uncertain. The proposed transfer-cum-tax scheme reduces this uncertainty. This would increase the benefits from scrutiny, leading to greater scrutiny and, therefore, more public goods and better opportunities for the population.[20] Taxation is recognized in the literature as a key factor in building accountability in government and public policies (Besley and Persson 2009). To alleviate the problem, the conversion of resource revenues into first cash transfers and then tax revenues might help reduce political sector distortions and improve socioeconomic outcomes in RR countries.

Such schemes are not without challenges, however. Governments may struggle to administer such wide-scale cash transfer programs, especially lower-income countries already struggling to invest resource revenues effectively. Further, the taxation of those cash transfers may incur a cost that might exceed any efficiency gains from the increased scrutiny. Capital-scarce economies have a lot of urgent, unmet public investment needs, and therefore large-scale public investment projects may yield a higher social rate of return than distributing revenues as cash transfers and taxing some fraction back for public use. Finally, there remain serious concerns about governments' ability to manage inflationary pressures that large-scale cash distribution might entail.

Conclusion

The average level of human capital per capita is lower in RR countries compared with non-RR countries. Evidence suggests that an abundance of nonrenewable resources can distort the economy away from the accumulation of human capital, including via the Dutch disease. Consequently, the accumulation of human capital per capita is slower in RR countries. Further, the distribution of human capital between men and women is more unequal in RR countries compared with non-RR countries, and the size of public sector employment is larger.

Countries may be able to mitigate each of these distortions, and this may have the additional benefit of boosting overall levels of human capital accumulation and value. First, countries may be able to mitigate Dutch disease by investing rents from resource extraction in the domestic economy. By boosting productivity and flattening supply curves, governments may be able to alleviate the effect of rising nontraded sector prices. Second, by addressing gender distortions in education and the labor market, governments may be able to alleviate a male bias in human capital in RR countries, a bias that may lead to suboptimal levels of human capital accumulation as well as associated inequities. Finally, via innovative revenue distribution methods, such as direct cash transfers, governments may be able to alleviate an oversized public sector, which can result from resource abundance, as resource revenues would not directly fuel the general budget and would transit first through citizens with significant incentives to scrutinize the use and efficiency of public spending. This in turn may boost human capital valuation by reallocating labor to emerging private activities with higher productivity and thus provide benefits from circumventing the public sector.

Annex 12A: Additional Tables and Figures

TABLE 12A.1 Resource-Rich Countries

Country	Region	Hydrocarbon-rich	Mineral-rich
Afghanistan	South Asia	No	Yes
Albania	Europe and Central Asia	Yes	No
Algeria	Middle East and North Africa	Yes	No
Angola	Sub-Saharan Africa	No	No
Azerbaijan	Europe and Central Asia	Yes	No
Bahrain	Middle East and North Africa	Yes	No
Bolivia	Latin America and the Caribbean	Yes	No
Botswana	Sub-Saharan Africa	Yes	No
Brunei Darussalam	East Asia and Pacific	No	Yes
Cameroon	Sub-Saharan Africa	No	Yes
Central African Republic	Sub-Saharan Africa	No	Yes
Chad	Sub-Saharan Africa	Yes	No
Chile	Latin America and the Caribbean	Yes	No
Congo, Dem. Rep.	Sub-Saharan Africa	Yes	Yes
Congo, Rep.	Sub-Saharan Africa	Yes	No
Côte d'Ivoire	Sub-Saharan Africa	Yes	No
Ecuador	Latin America and the Caribbean	Yes	No
Equatorial Guinea	Sub-Saharan Africa	Yes	No
Gabon	Sub-Saharan Africa	No	Yes
Ghana	Sub-Saharan Africa	No	Yes
Guatemala	Latin America and the Caribbean	Yes	No
Guinea	Sub-Saharan Africa	No	Yes
Guyana	Latin America and the Caribbean	No	Yes
Indonesia	East Asia and Pacific	Yes	No
Iran, Islamic Rep.	Middle East and North Africa	Yes	No
Iraq	Middle East and North Africa	Yes	No
Kazakhstan	Europe and Central Asia	Yes	No
Kyrgyz Republic	Europe and Central Asia	No	Yes
Lao PDR	East Asia and Pacific	No	Yes
Liberia	Sub-Saharan Africa	No	Yes
Libya	Middle East and North Africa	Yes	No
Madagascar	Sub-Saharan Africa	Yes	No

(continued on next page)

TABLE 12A.1 Resource-Rich Countries *(continued)*

Country	Region	Hydrocarbon-rich	Mineral-rich
Mali	Sub-Saharan Africa	Yes	No
Mauritania	Sub-Saharan Africa	No	Yes
Mexico	Latin America and the Caribbean	No	Yes
Mongolia	East Asia and Pacific	Yes	Yes
Mozambique	Sub-Saharan Africa	No	Yes
Niger	Sub-Saharan Africa	No	Yes
Nigeria	Sub-Saharan Africa	Yes	No
Norway	Europe and Central Asia	Yes	No
Oman	Middle East and North Africa	Yes	No
Papua New Guinea	East Asia and Pacific	No	Yes
Peru	Latin America and the Caribbean	Yes	Yes
Qatar	Middle East and North Africa	Yes	No
Russian Federation	Europe and Central Asia	Yes	No
São Tomé and Príncipe	Sub-Saharan Africa	Yes	No
Saudi Arabia	Middle East and North Africa	Yes	No
Sierra Leone	Sub-Saharan Africa	No	Yes
South Sudan	Sub-Saharan Africa	No	No
Sudan	Sub-Saharan Africa	Yes	No
Suriname	Latin America and the Caribbean	No	Yes
Syrian Arab Republic	Middle East and North Africa	Yes	No
Tanzania	Sub-Saharan Africa	Yes	No
Timor-Leste	East Asia and Pacific	No	Yes
Togo	Sub-Saharan Africa	Yes	No
Trinidad and Tobago	Latin America and the Caribbean	Yes	No
Turkmenistan	Europe and Central Asia	Yes	No
Uganda	Sub-Saharan Africa	No	Yes
United Arab Emirates	Middle East and North Africa	Yes	No
Uzbekistan	Europe and Central Asia	Yes	Yes
Venezuela, RB	Latin America and the Caribbean	Yes	No
Vietnam	East Asia and Pacific	Yes	No
Yemen, Rep.	Middle East and North Africa	Yes	No
Zambia	Sub-Saharan Africa	No	Yes

Sources: IMF 2012; Venables 2016.
Note: Regions are the World Bank regional classifications.

TABLE 12A.2 Resource-Rich Countries in Sub-Saharan Africa

Angola	Mali
Botswana	Mauritania
Cameroon	Mozambique
Central African Republic	Niger
Chad	Nigeria
Congo, Dem. Rep.	São Tomé and Príncipe
Congo, Rep.	Sierra Leone
Côte d'Ivoire	South Sudan
Equatorial Guinea	Sudan
Gabon	Tanzania
Ghana	Togo
Guinea	Uganda
Liberia	Zambia
Madagascar	

Sources: IMF 2012; Venables 2016.

TABLE 12A.3 Average Difference in Human Capital per Capita between Resource-Rich Countries and Non-Resource-Rich Countries, by Region, Excluding High-Income Countries, 1995–2018
constant 2018 US$

Region and resource category	1995	2000	2005	2010	2015	2018
East Asia and Pacific						
Non-RR	25,233	35,086	49,714	70,233	98,895	117,725
RR	15,841	14,886	17,376	22,803	22,733	25,718
Gap (RR – non-RR)	–9,392	–20,200	–32,338	–47,431	–76,162	–92,008
Europe and Central Asia						
Non-RR	13,263	13,601	17,672	20,278	19,706	22,969
RR	21,659	23,129	32,070	46,876	49,915	51,944
Gap (RR – non-RR)	8,397	9,528	14,397	26,598	30,210	28,975
Latin America and the Caribbean						
Non-RR	48,974	51,783	54,103	60,588	65,483	63,433
RR	36,194	39,922	41,193	40,225	50,534	46,944
Gap (RR – non-RR)	–12,779	–11,861	–12,910	–20,362	–14,949	–16,490

(continued on next page)

TABLE 12A.3 Average Difference in Human Capital per Capita between Resource-Rich Countries and Non-Resource-Rich Countries, by Region, Excluding High-Income Countries, 1995–2018 *(continued)*

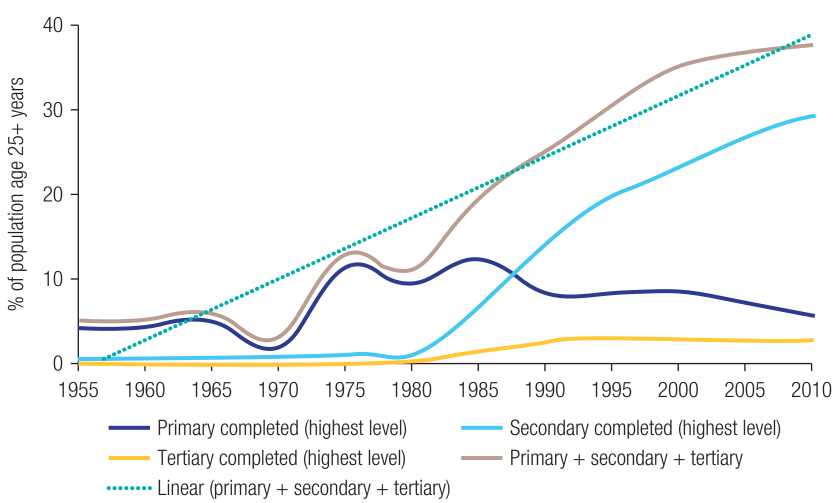
constant 2018 US$

Region and resource category	1995	2000	2005	2010	2015	2018
Middle East and North Africa						
Non-RR	10,086	11,474	11,496	13,390	13,564	14,163
RR	16,699	14,869	14,871	18,063	19,790	20,051
Gap (RR – non-RR)	6,613	3,395	3,375	4,673	6,226	5,888
North America						
Non-RR	—	—	—	—	—	—
RR	—	—	—	—	—	—
Gap (RR – non-RR)	—	—	—	—	—	—
South Asia						
Non-RR	6,020	7,158	8,776	10,115	12,856	15,179
RR	—	—	1,977	3,006	3,707	3,669
Gap (RR – non-RR)	—	—	–6,799	–7,109	–9,149	–11,509
Sub-Saharan Africa						
Non-RR	11,012	10,149	10,259	11,391	13,975	14,784
RR	6,012	5,603	6,437	9,728	10,481	10,603
Gap (RR – non-RR)	–5,000	–4,546	–3,822	–1,663	–3,494	–4,181

Source: World Bank staff calculations.

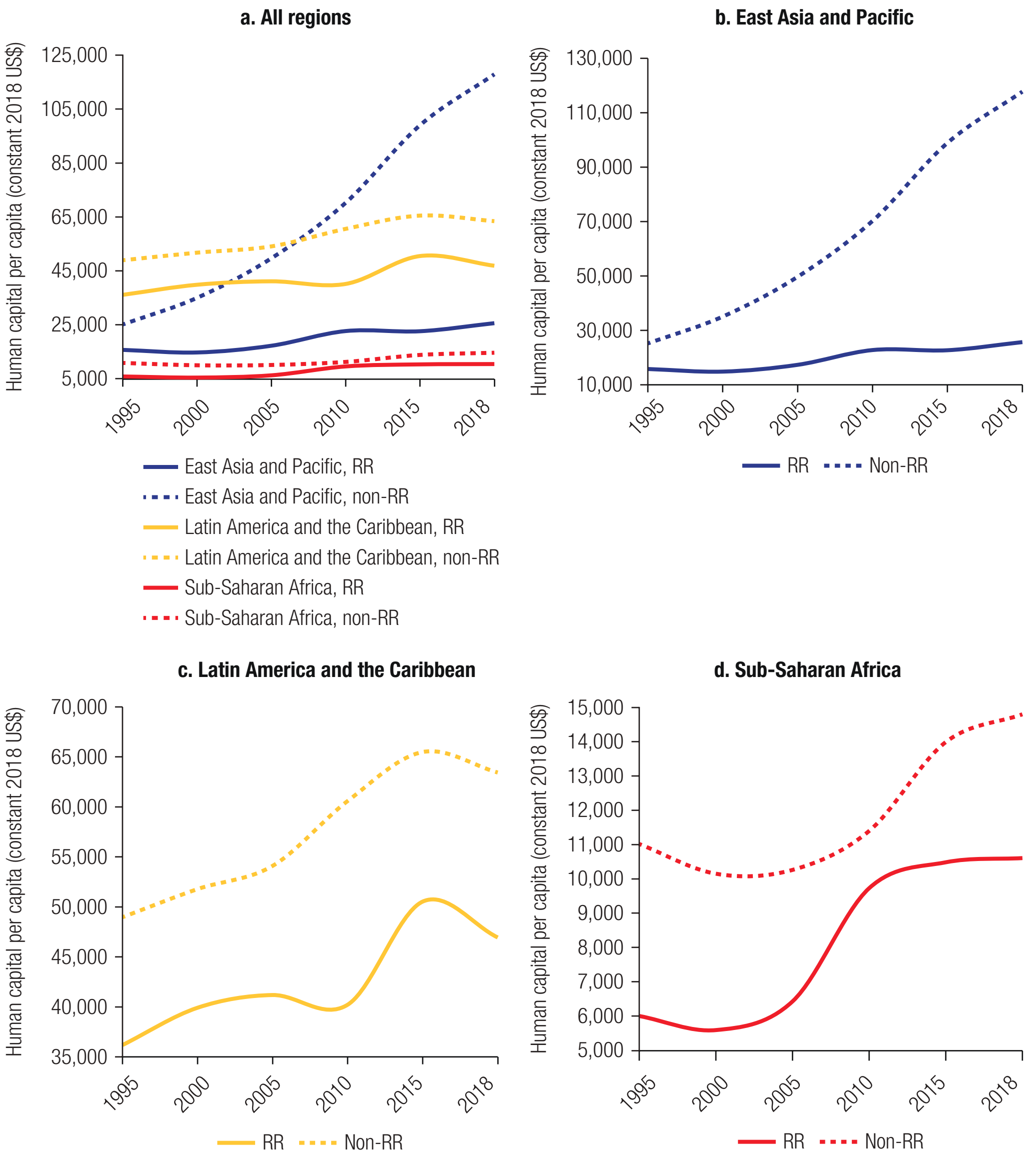
Note: RR = resource-rich countries; non-RR = non-resource-rich countries; — = not available. The classification of resource-rich countries is taken from IMF (2012) and Venables (2016). High-income countries (as defined in the Atlas Method, https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2020-2021) are excluded from regional aggregates.

FIGURE 12A.1 Evolution of the Highest Level of Educational Attainment in Botswana, 1955–2010



Source: Barro and Lee 2013, Barro-Lee Educational Attainment Dataset, version 2.2 (accessed December 2020).

FIGURE 12A.2 Average Difference in Human Capital per Capita between Resource-Rich Countries and Non-Resource-Rich Countries, Selected Regions, Excluding High-Income Countries, 1995–2018



Source: World Bank staff calculations.
Note: RR = resource-rich countries; non-RR = non-resource-rich countries. The classification of resource-rich countries is from IMF (2012) and Venables (2016). High-income countries (defined using the Atlas Method) are excluded from the regional aggregates.

Notes

1. For instance, Botswana succeeded in converting its diamond rents into higher educational attainment for its adult population (see figure 12A.1, in annex 12A).
2. The argument can be reversed: resource abundance can negatively affect the degree of democratization and the institutional framework (Ahmadov 2013; Hendrix 2018; Wigley 2018).
3. In this chapter we use the term *resource rich* for all countries that have at least 20 percent of exports or 20 percent of fiscal revenue from nonrenewable natural resources (oil, gas, coal, or minerals) over 2006–10 while *non-resource-rich* countries are the rest of the world.
4. The definition of RR countries is taken from IMF (2012) and Venables (2016) and is detailed in the first section of this chapter.
5. IMF (2012) and Venables (2016) define RR countries as any country deriving at least 20 percent of exports or 20 percent of fiscal revenue from nonrenewable natural resources over 2006–10. In addition, a subcategory of countries that do not necessarily meet the thresholds are included in their list as *prospective natural resource–exporting low-income and lower-middle-income countries*: Afghanistan, the Central African Republic, Ghana, Guatemala, the Kyrgyz Republic, Madagascar, Mozambique, São Tomé and Príncipe, Sierra Leone, Tanzania, Togo, and Uganda (IMF 2012, 49). This chapter keeps these countries on the list of RR countries. Kuwait and South Africa are not included because of the lack of data for Kuwait for 2006–10, South Africa was close but did not meet the thresholds for that period, and both countries are not low-income or lower-middle-income, so they do not enter to the category of prospective countries.
6. The World Bank regional classifications are used as a reference, https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.
7. The qualitative interpretation is reversed for Europe and Central Asia when excluding high-income RR countries, as 27 of 28 high-income countries in this region are also non-RR countries (the only exception is Norway, which is an RR country with a high-income level). The results when excluding high-income countries for every region are available in table 12A.3 in annex 12A.
8. RR countries in the Middle East and North Africa overperform the level of human capital per capita of non-RR countries in the same region. But when considering the whole sample of countries, they underperform compared with non-RR countries with similar levels of gross domestic product per capita (see figure 12.3).
9. Europe and Central Asia is not considered because 27 non-RR countries in the region (of 40) are high-income countries and only one (Norway) is an RR country and a high-income country. The Middle East and North Africa region is not considered because the region's five major regional RR countries (Bahrain, Oman, Qatar, Saudi Arabia, and the United Arab Emirates), of 11 countries, are high-income countries and only three countries (Israel, Kuwait, and Malta) are non-RR countries with high income levels. North America is de facto discarded because it is composed of Bermuda, Canada, and the United States. South Asia is not considered because of limited comparison data; Afghanistan is the only RR country in that region.

10. The qualitative interpretation, including the rapid accumulation of human capital per capita in East Asia and Pacific between 1995 and 2018, does not change when high-income countries are excluded. The results when excluding high-income countries for every region are available in figure 12A.2, in annex 12A.
11. In endogenous growth theory, learning by doing is a concept by which productivity is achieved through practice, self-perfection, and minor innovations.
12. For this exercise, the ratio of public employment over the whole population (less precise for the size of the public sector, as it includes children and elderly people) is used instead of the ratio of public employment over the working-age population.
13. The score for government effectiveness reflects the perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. For more details, see the Worldwide Governance Indicators.
14. See van der Ploeg and Venables (2011, 3) for a list of references advocating the implementation of a sovereign wealth fund.
15. The bird-in-hand hypothesis assumes that all resource revenue is put in a sovereign wealth fund and incremental consumption is restricted to the interest earned on the fund.
16. In addition, Cust and Manley (2018) note that sovereign wealth funds may not be a satisfying solution to decarbonize the economy, if financial assets held are linked to fossil fuel extraction—as is often the case in diversified financial portfolios.
17. The full list includes Bahrain, Brunei Darussalam, Chile, Norway, Oman, Qatar, Saudi Arabia, Trinidad and Tobago, and the United Arab Emirates.
18. This could occur as a reversal of the distortions described by Ross (2008), where, for example, he found that oil production can reduce the female labor force and thus reduce women's political influence. This could therefore have an impact on the kinds of norms and political institutions that dominate in a society.
19. Devarajan and Singh (2012) illustrate this point with the following examples from three Central African fossil fuel exporters. Cameroon spends US$50 per capita on health, with the epidemiological profile of countries that spend US$10 per capita. Road maintenance costs are double the African average, and three-quarters of contracts circumvent the regular procurement system. Chad has the highest cost of classroom construction in Africa, and that cost represents four times the next most expensive country. Despite a larger public sector and about the same amount of health spending per capita, immunization rates are one-third those in Senegal, for instance. Finally, the leakage rate for nonwage health spending is close to 99 percent. The Republic of Congo has 47 percent transmission losses in electricity; the average for Africa is 27 percent.
20. On empirical evidence on scrutiny, Weigel (2020) shows that the introduction of property taxes in the Democratic Republic of Congo increased citizen participation in town hall meetings and evaluations of public projects at local levels. The results provide support to the idea that broadening the tax base has a "participation dividend" that works even in the context of an RR-country with a weak state.

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13

Natural Allies: Wealth and Sovereign Environmental, Social, and Governance Frameworks

Ekaterina Gratcheva and Dieter Wang

Main Messages

- Financial markets have started adopting sustainable development goals into mainstream discussions. Sovereign environmental, social, and governance (ESG) scores that guide sustainable finance have an ingrained income bias that potentially diverts capital flows toward richer countries at the expense of poorer countries.
- Comprehensive wealth data are uniquely suited to inform sovereign ESG because they (1) put a dollar value on natural assets, (2) adopt a forward-looking perspective, and (3) have a long history of curated data that are comparable across 23 years and 146 countries.
- The environmental pillar of sovereign ESG frameworks traditionally relies mostly on a resource's environmental materiality (for example, forest cover) and less on its economic materiality (for example, forest wealth). As wealth measurement exceeds a mere stock-taking exercise and reflects the resource's long-term economic benefits, it can complement environmental indicators for decision-makers.
- The adoption of wealth data has been constrained by their five-year frequency and late availability. This edition of *The Changing Wealth of Nations* (CWON) updates the frequency to annual and increases the potential applications of the data.

Financial Markets and Sovereign ESG Frameworks

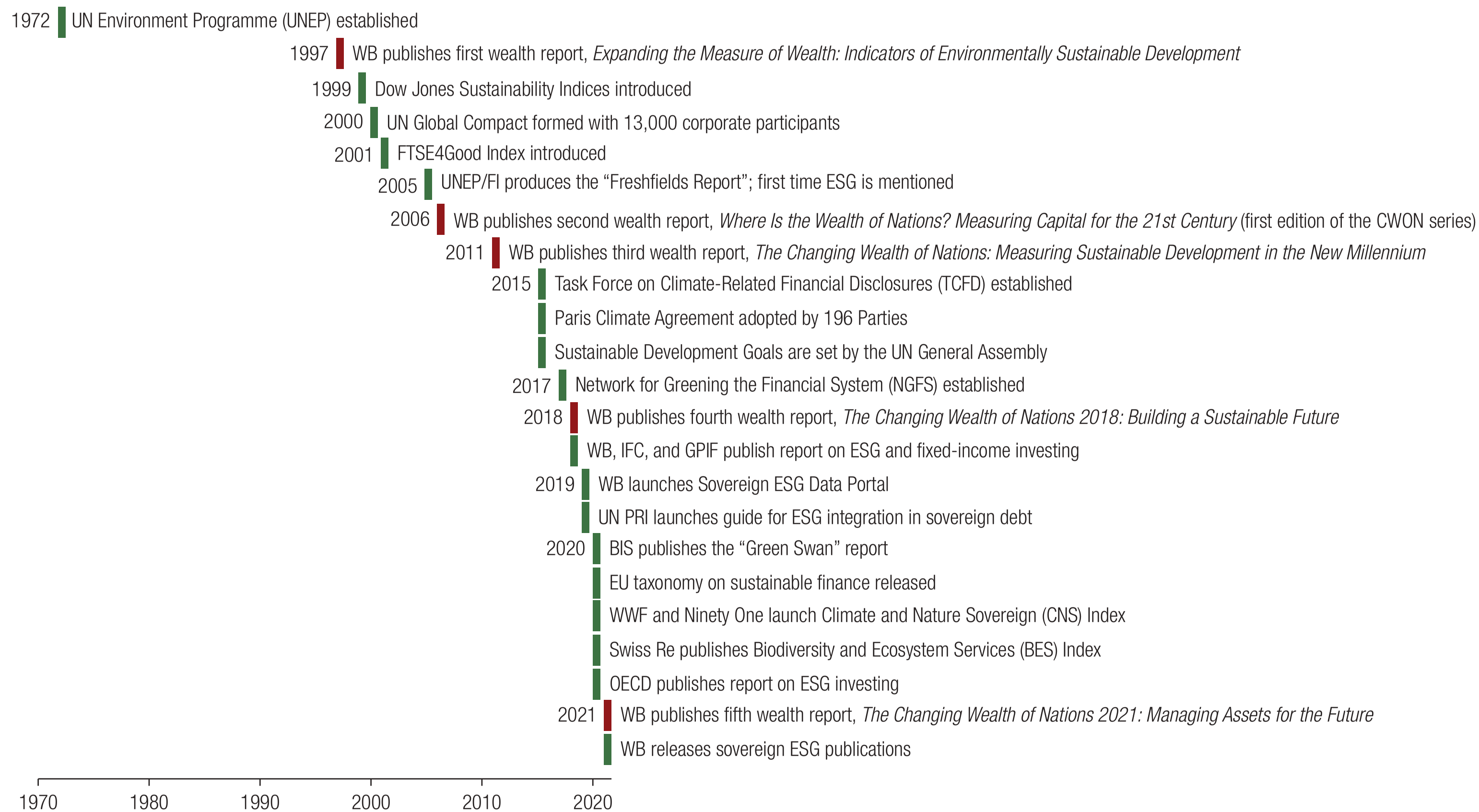
Driven by investor demand and regulatory requirements, financial markets are undergoing a paradigm shift that moves sustainable finance from the periphery to the center of financial discussions (Boitreaud et al. 2020). The introduction of the United Nations Sustainable Development Goals (SDGs) and the Paris Declaration on Climate Change in 2015 have helped galvanize the societal shift to ensure a sustainable future. The pace of ESG integration,[1] which has become the most prevalent form of sustainable finance, has accelerated over recent years. The International Monetary Fund, Network for Greening the Financial System, Organisation for Economic Co-operation and Development, World Bank, and many public, academic, and financial institutions and organizations have been extensively documenting how these changes affect the evolving financial ecosystem and investment decisions across different asset classes.

Global risk perception has evolved significantly over the past decade, with the top five risks being dominated by environmental and societal concerns: (1) extreme weather conditions, (2) climate action failure, (3) human-made environmental damage, (4) infectious diseases, and (5) biodiversity loss (WEF 2020). Dasgupta (2021) frames the loss of natural capital as part of a global asset management problem—one that humanity has been mismanaging. Grasping its immediate implications is challenging because the consequences play out decades into the future. Wealth accounting helps bridge this gap for decision-makers because its main purpose is to express a country's long-term sustainable growth potential in present terms. Similar to how a healthy corporate balance sheet is the precondition for a steady stream of future cash flows, a country requires a healthy balance sheet to ensure sustainable economic development in the future. Neglecting wealth in favor of growth likely exacerbates the long-term consequences of short-term gains.

Evolving over the past decade, ESG investing has started to shift from "purpose neutral" to "purposeful" (J.P. Morgan 2020), from "value" to "values" (Eccles and Stroehle 2018), and from a perspective of ESG not only as another input into financial decision-making but also as an output (Gratcheva, Gurhy, Emery, et al. 2021), thereby aligning this investment approach with the concept of sustainable development. Market participants are increasingly accepting that the way to mitigate ESG risks in emerging markets in the long run is by fostering sustainable growth outcomes. This ongoing evolution of the financial industry toward a greater focus on development outcomes is fueling the growing demand for sustainable finance and more sustainable investment frameworks and practices. Figure 13.1 illustrates the key milestones in sovereign ESG evolution.

Despite significant progress in ESG integration, analytics, and data for equities and corporate bonds, the development of ESG for sovereign bonds—the largest asset class—is still in the growth stage. In 2019, the total outstanding value of global bond markets amounted to US$106 trillion, exceeding global stock market capitalization of US$95 trillion and US$21 trillion in bonds issued, compared with US$541 billion in new

FIGURE 13.1 Timeline of Significant ESG Catalysts and Enablers



Source: World Bank.

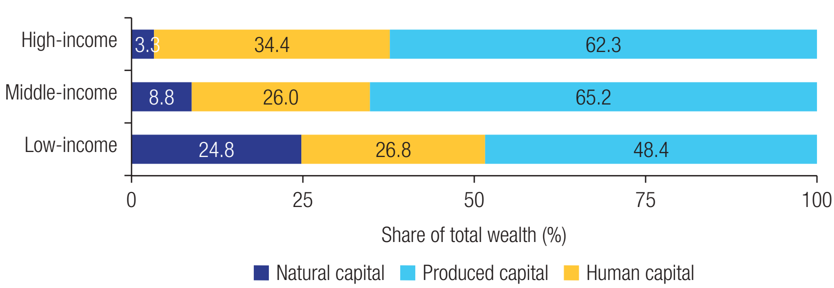
Note: ESG finds its roots in early environmental efforts but has gained attention and momentum in recent years. BIS = Bank for International Settlements; CWON = *The Changing Wealth of Nations*; ESG = environmental, social, and governance; EU = European Union; GPIF = Government Pension Investment Fund; IFC = International Finance Corporation; OECD = Organisation for Economic Co-operation and Development; UN = United Nations; UNEP/FI = United Nations Environment Programme Finance Initiative; WB = World Bank; WWF = World Wide Fund for Nature.

equity (SIFMA 2019). The sovereign ESG landscape has started to change with notable developments across the industry over the past couple of years. While the recent focus has been on the growth of green-, social-, and sustainability-related bonds, these bonds constitute only a small fraction of the sovereign bond universe; they amount to just US$108 billion. For African countries, only US$817 million of US$1 trillion in all African sovereign bonds belong to this emerging category. The industry has started to integrate ESG factors into the investment process for conventional sovereign bonds in an effort to reflect sustainability preferences across the entire sovereign bond asset class.

The 2020 pandemic became a strong reminder for the pivotal role sovereigns play in coordinating sustainable development and building resilience globally and nationally. Sovereigns are the key stakeholders in setting national policies—including in public health, environmental, and sustainable infrastructure investment—that drive the country's development and its response to crises. They are also the key to shaping international agreements, such as the Paris Climate Agreement and SDGs. Thus, investors are increasingly focusing on investment opportunities that not only meet their risk and return objectives but also contribute to measurable sustainable outcomes. This approach of balancing financial materiality and environmental materiality—the so-called dual materiality—is defining the evolution of sustainable finance going forward (Gratcheva, Gurhy, Emery, et al. 2021).

Sovereign ESG scores are highly correlated with gross national income, which overemphasizes produced capital over other forms of capital (Gratcheva, Emery, and Wang 2020). Figure 13.2 provides a breakdown of total wealth into natural, produced, and human capital. Due to the ingrained income bias, which is explained in box 13.1 later in this chapter, current ESG scores favor rich countries and therefore possibly divert funding away from lower-income countries, where capital is needed to meet the SDGs, the nationally determined contributions of the Paris Agreement, and other

FIGURE 13.2 Wealth Composition, by Income Group, 2018



Source: World Bank staff calculations.
Note: This figure shows how natural capital's share of total wealth drops as countries climb the development ladder. It is replaced by the growing importance of produced capital, which is highly correlated with gross domestic product. For this figure, net foreign assets are excluded from the calculation of total wealth.

development needs. Not only could the ingrained income bias serve as an explanation for the lack of impact ESG investors seek, what is more troubling is that ESG investing may unintentionally harm sustainable development. Measuring a nation's wealth more comprehensively is necessary to start overcoming these biases.

Access to capital markets plays an important role in countries' development by providing an important channel of financing for the real economy, national infrastructure, and social and other needs. The ability of countries to raise funds on favorable terms depends on a number of factors, recently on the market participants' application of sovereign ESG scores to assess the country's long-term sustainability and creditworthiness (Gratcheva, Gurhy, Skarnulis, et al. 2021). Although the scores have been used predominately in the context of sovereign bonds, they are not tied to a specific instrument. Instead, sovereign ESG scores help inform a country's overall risk and investment profile (Gratcheva, Gurhy, Emery, et al. 2021). The wealth accounting data serve as a valuable foundation on which these profiles can be formed, even for countries with less developed markets, thanks to their wide and consistent coverage of 146 countries.

Wealth on a Country's Balance Sheet

Gross domestic product (GDP) as a measure of economic well-being or living standards has long been criticized. As natural capital and ecosystem services have gained momentum in current policy discussions, the shortcomings of GDP have become more and more apparent. Not only is GDP inadequate for providing a complete picture of an economy's situation and prospects (Coyle et al. 2019), it also does not reflect the depletion of subsoil assets, loss of species abundance, or agricultural damage resulting from extreme weather events. Furthermore, GDP does not account for positive environmental policies such as reforestation efforts, the adoption of organic agriculture, or preservation of biodiversity and endangered species.

Exploiting natural resources for short-term economic gains comes at the cost of long-term sustainable growth potential. Resource-dependent economies may experience short-term growth boosts by relying on natural resource rents. If these rents are not reinvested into other types of capital, the country's economy may fall victim to the natural resource curse or the Dutch disease (Gylfason 2001; van der Ploeg 2011; Venables 2016). However, these long-term consequences remain unquantified, as decision-makers lack an adequate monetary assessment of what is lost in terms of future rents. According to Joseph Stiglitz, winner of the Nobel Prize for Economics, "it's like grading a corporation based on one day's cash flow and forgetting to depreciate assets and other costs" (Stiglitz 2006). This calls for a measure of a country's assets that not only takes stock of current agricultural land in square kilometers but also conveys the potential "lifetime earnings" of the land in dollar amounts.

Wealth accounting quantifies the lifetime earnings of a country's assets in monetary terms. The wealth methodology provides a robust, quantitative framework for thinking about sustainability in terms of natural, produced, and human capital. For instance, human capital is calculated as the discounted expected lifetime earnings of a population. A similar rationale applies to the valuation of natural resources. A country's fossil fuel wealth is calculated as the discounted value of future resource rents until this nonrenewable resource is depleted. Renewable resources, such as forests or agricultural land, distinguish themselves in that their discounting horizon depends on the rate of extraction versus replacement. For instance, forest capital is a function of (inflation-adjusted) unit rents, production quantities, and the difference between deforestation and reforestation or afforestation rates. In principle, renewable resources can produce rents in perpetuity.

Addressing Sovereign ESG Challenges

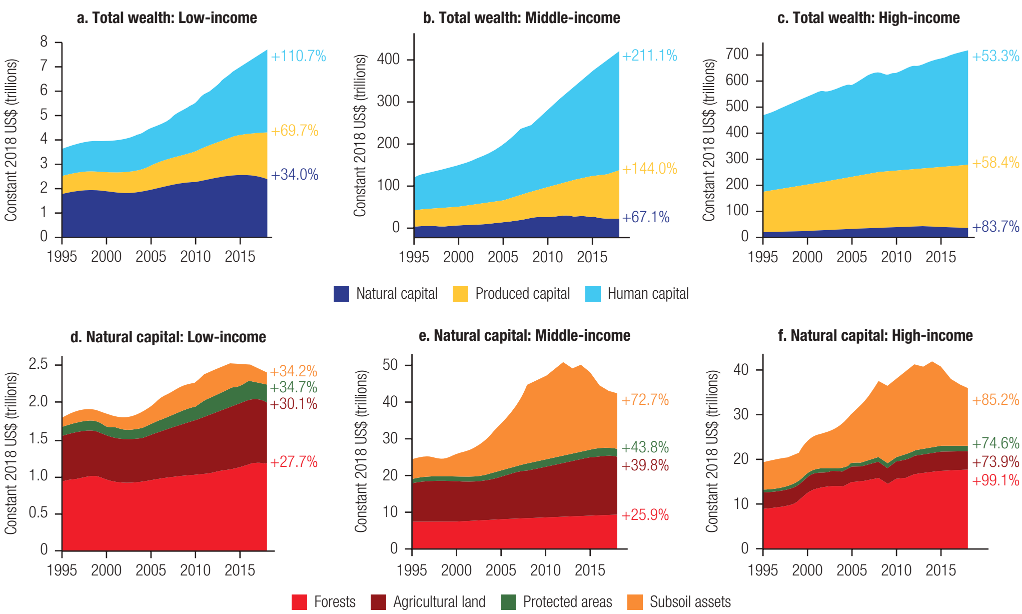
Application of sovereign ESG scores produced by ESG providers does not necessarily meet the intended goal of incorporating sustainability objectives within the investment process.[2,3] This section outlines three challenges that affect various sovereign ESG scores and discusses how wealth data are a well-suited remedy.

Challenge 1: Lack of Economic Materiality

Sovereign ESG assessments or sovereign ESG scores that rely only on raw environmental data potentially underestimate the economic materiality of environmental factors. The same plot of forest land matters relatively less to a high-income country, whose economy relies more on human capital and produced capital, than it does to a country whose economy depends heavily on timber goods or international tourism (see figure 13.2 and figure 13.3). ESG scores that use only quantities as inputs, such as percentage of forest cover, likely understate the economic materiality of the resource. To illustrate this point further, consider nonrenewable resources such as oil or minerals. The valuation of such assets is the product of the remaining quantity and its market price. Yet renewable resources, such as forests or agricultural land, are usually incorporated only in noneconomic units.

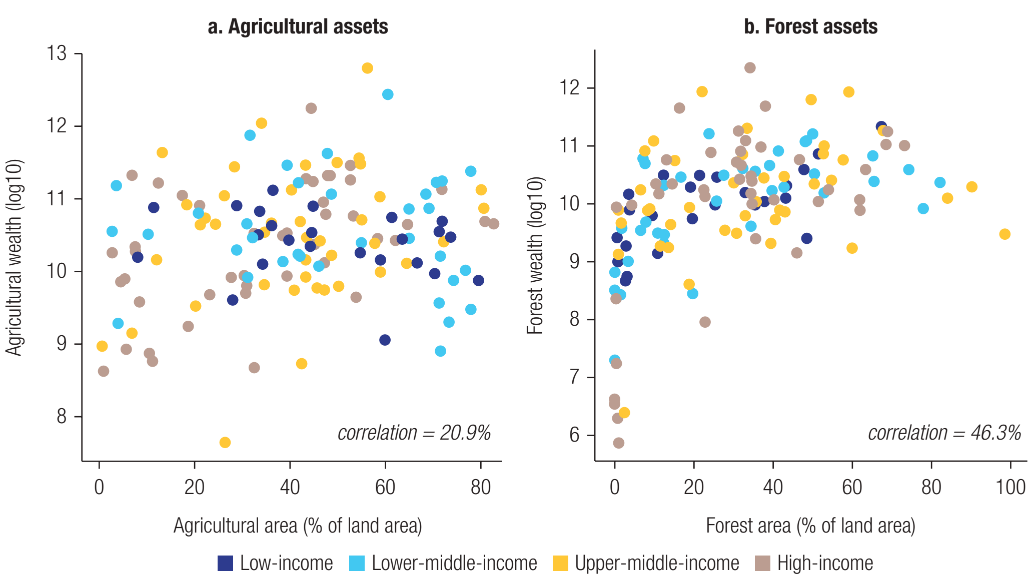
Environmental materiality does not imply economic materiality. Figure 13.4 illustrates this discrepancy. The horizontal axes depict the environmental data, that is, agricultural and forest areas as percentages of total land area. The vertical axes show the corresponding wealth variables, which represent assets on a country's balance sheets. The figure covers 146 countries with data from 2016. The low correlations show that the economic valuation of agricultural wealth is largely unrelated to its geographic size. This also holds true for forest assets but to a lesser degree. Wealth data, therefore, contain additional information that is not captured in raw environmental data. Because wealth accounts are constructed to measure economic materiality and long-term sustainable growth potential, sovereign ESG methodologies would benefit from including them in addition to the underlying environmental metrics.

FIGURE 13.3 Development of Wealth Accounts, by Income Group, 1995–2018



Source: World Bank staff calculations.

FIGURE 13.4 Environmental Materiality versus Economic Materiality in Agricultural and Forest Assets



Source: World Bank staff calculations from Sovereign ESG Data Portal.

Note: The horizontal axes show environmental variables, while the vertical axes show their wealth counterparts (log10 transformation).

Challenge 2: Ingrained Income Bias

Although sovereign ESG integration has brought into focus the issue of sovereign sustainability, current ESG frameworks face fundamental challenges that limit their sustainability impact. While the growth of ESG integration across all segments of capital markets to incorporate nonfinancial considerations is driven by an interest in aligning investments with sustainability objectives, it is worth examining the direction of capital flows as a result of ESG integration. Figure B13.1.1 in box 13.1 clearly shows a common theme: the higher a country scores on national income, the higher the country scores on the ESG spectrum. This finding has profound implications. Investors who are interested in promoting sustainable growth through ESG investment may find themselves potentially aggravating existing funding gaps and wealth disparities for lower-income countries. Since "higher is better" in the ESG domain, a sovereign ESG investor faces possibly perverse investment incentives.

Further investigation finds that sovereign ESG scores are strongly income biased. Higher ESG scores are correlated with higher prosperity. In fact, the relationship in figure B13.1.1 is dominated by the levels of development and income, as about 90 percent of sovereign ESG scores are explained by the country's national income (Gratcheva, Emery, and Wang 2020). Prosperous countries score higher on all three ESG dimensions, simply because they are prosperous. Richer countries have higher environmental scores because they have the capacity to designate and enforce national parks or put large swaths of land under conservation. More important, the same countries will score high on the social and governance dimensions because strong institutions and higher participation in the labor force are the preconditions for growth. Higher ESG scores are, therefore, not necessarily the best indicator for sustainable growth. More problematic, this bias is ingrained. A country that finds itself in the bottom-left corner of figure B13.1.1 has little chance to move toward the top-right in the short run. The level of development is the result of decades and centuries of economic growth, and no short-term efforts will significantly impact a country's location in figure B13.1.1.

This structural challenge in the sovereign ESG scores calls for income adjustment, which is not trivial. Gratcheva, Emery, and Wang (2020) describe methods of income adjusting that have been popularized by industry practitioners and point out some of their shortcomings. This chapter advocates looking at recent wealth developments instead of focusing on the level of wealth (see box 13.2). Rather than comparing across countries, as in figure B13.1.1, the suggestion is to look within countries. ESG scores based on this approach are unaffected by the ingrained income bias because it compares countries with themselves at an earlier point in time. Countries' environmental performances are assessed on a level playing field and recent environmental efforts come to the fore. This approach does not invalidate existing sovereign ESG scores but presents a complementary picture.

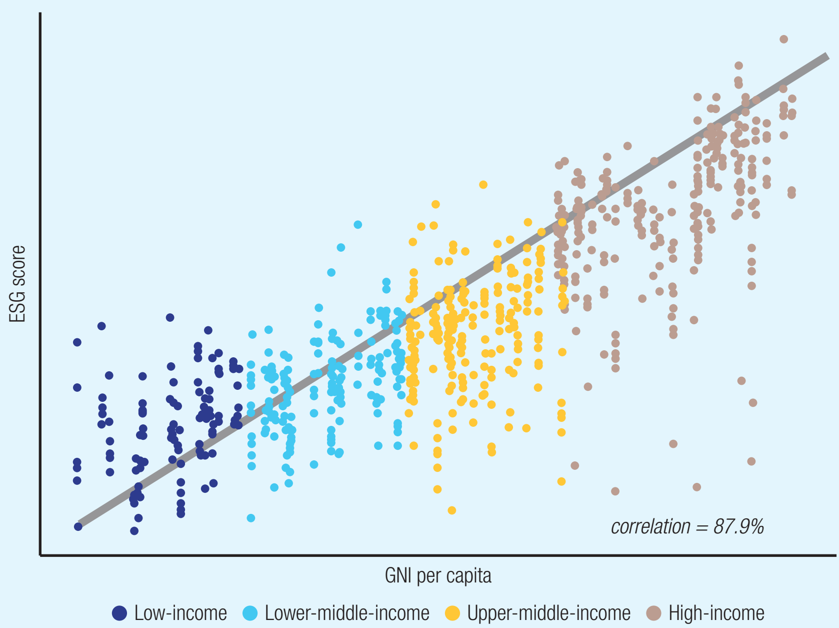
Income adjustment through recent environmental performance requires time variation. To assess the effects of recent environmental

BOX 13.1 What Is Ingrained Income Bias?

Several studies (Boitreaud et al. 2020; Gratcheva, Emery, and Wang 2020) document that countries scoring high on environmental, social, and/or governance (ESG) scores also tend to rank high in income and development levels (figure B13.1.1). This is not surprising, because high labor participation, political stability, rule of law, access to electricity, carbon dioxide emissions, and forest depletion rates do not exist in a vacuum. These indicators are inputs and outputs of long-term growth and development. This phenomenon—the ingrained income bias—is not limited to ESG scores; it is ingrained in any type of cross-country analysis that compares development-related indicators. In econometric terms, these types of analyses suffer from endogeneity, or specifically, omitted variable bias (Wang 2021). Not accounting for the ingrained income bias leads to two important consequences:

1. The *income bias* leads to perverse investment outcomes. Tilting investment portfolios toward higher ESG scores likely steers funding flows away from lower-income countries and toward richer countries, effectively rewarding them for their prosperity.
2. The *ingrainedness* leads to disheartening policy incentives. Policy efforts in the short run are unlikely to affect a country's development or income level, which are the result of decades or centuries of economic development.

FIGURE B13.1.1 Sovereign ESG Scores and the Ingrained Income Bias



Source: World Bank staff calculations.
Note: The vertical axis depicts the (normalized) environmental, social, and governance (ESG) scores of six leading sovereign ESG providers, where higher values indicate better ESG performance. The horizontal axis shows the (normalized) gross national income (GNI) per capita for all 133 countries in 2017. The term *ESG providers* refers to companies that provide ESG scores for incorporation into investment decisions. ESG providers differ from credit rating agencies, as the latter have an explicit mandate to assess an entity's ability to repay its debt.

BOX 13.2 Wealth Data and Sovereign Bonds

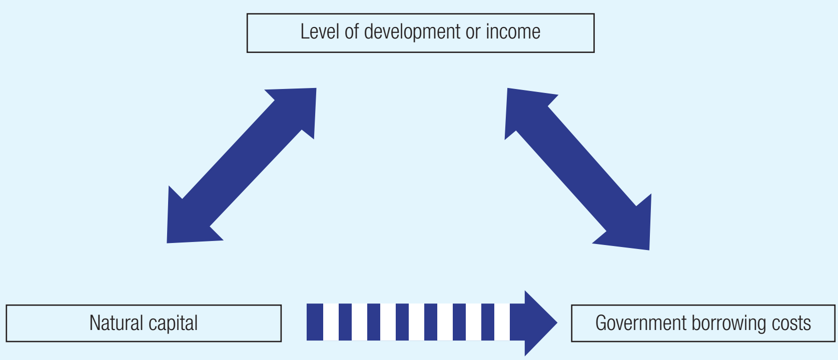
Gratcheva, Gurhy, and Wang (2021) and Wang (2021) examine the role of natural capital in sovereign bond yields using a cross-section of 37 countries, comprising 20 A-rated countries (average long-term debt rating between AAA and A–) and 17 B-rated countries (ratings between BBB+ and BB–) between January 2009 and December 2018.[a]

The authors estimate the effect of 1 percent growth in natural capital on the 10-year bond yield from two perspectives. When comparing bond yields with natural capital across countries, a positive association emerges: countries that are richer in natural capital tend to have higher borrowing costs. While this could be explained through the natural resource curse[b] or long-term growth arguments,[c] the authors strongly caution against drawing any conclusions based on pure cross-country analyses due to the ingrained income bias (see figure B13.1.1 in box 13.1).

Instead, the authors advocate the within-country perspective, which measures the effect of *recent* environmental performance on *recent* changes in bond yields (see figure B13.2.1). This brings countries onto a level playing field and largely removes the ingrained income bias. After adopting the appropriate statistical framework, the authors find a negative relationship: as a country grows richer in natural capital, borrowing costs tend to drop. This finding is robust against the inclusion of various macrofinancial controls, wealth variables, and common bond factors.

After decomposing natural capital into renewables and nonrenewables, the authors find that growth in renewables lowers borrowing costs mostly in B-rated countries. A-rated countries are largely unaffected. This is likely because it is economically worthwhile to invest in these resources, such as agricultural and forest wealth, for countries that rely more on these resources for growth. Protected areas, which expanded predominantly in A-rated countries, are more likely luxury investments, because they are costly and nonproductive. Growth in this type of renewables would hypothetically raise borrowing costs in B-rated countries because they have the highest opportunity costs in terms of foregone agricultural or forest rents.

FIGURE B13.2.1 Hidden Role of Development and Income



Source: World Bank.
Note: The effect of natural capital on bond yields (dashed arrow) is likely biased due to the unobserved level of development or income. Without accounting for the ingrained income bias (see box 13.1), cross-country analyses may lead to erroneous conclusions.

a. Sovereign bond yields are often considered as a proxy for the cost of borrowing for governments. Lower bond yields therefore reflect more favorable financing conditions for countries.

b. The natural resource curse refers to the widely studied empirical phenomenon in which countries that are rich in natural resources often experience lower-than-expected growth.

c. As part of the long-term growth framework, Dasgupta and Heal (1974), Solow (1974), and Stiglitz (1974) discuss the essential role natural resources play in economic growth. In a growing economy, inflation erodes the purchasing power of money. Thus, bond investors demand higher yields on their investment as a compensation.

policies, a sufficiently long history of relevant indicators is necessary. The latest iteration of the wealth data presented in this book offers annual records between 1995 and 2018 and covers 146 countries. The 23 years of data lay a reliable foundation from which to assess recent performance. The main benefit of these data is the use of a consistent methodology over time. Frequent revisions in sovereign ESG methodologies have led to major shifts in country scores and consequently in ESG-related index products. The solid methodological framework also lends itself to be extended in the temporal and spatial dimensions (see box 13.3).

Challenge 3: Inconsistent Environmental Scores

Due to the dominating effect of the ingrained income bias, the social and governance scores are largely in agreement. However, the environmental scores are widely dispersed. Gratcheva, Emery, and Wang (2020) compare sovereign ESG scores across leading ESG providers and find that the social and governance scores have average pairwise correlations with each other of 85 and 71 percent, respectively. For the environmental scores, in contrast, the average correlation between ESG providers is 42 percent, ranging between –14 and 88 percent. The disagreement in the environmental pillar can be ascribed to the challenging data landscape and lack of consensus about what environmental performance means. Wealth data, especially natural capital and its components, are well suited to address both challenges.

BOX 13.3 Extending Wealth Data with Satellite Imagery and Machine Learning

WWF and World Bank (2020) describe the potential of spatial finance for environmental, social, and governance (ESG) investing and its appeal to financial markets. Remotely sensed data with higher temporal and spatial resolution can augment the relevance of wealth data. Their objective and globally consistent nature makes earth observation data an attractive choice for improving existing data sets. The wealth data are constructed on a well-founded economic framework that lends itself to extensions.

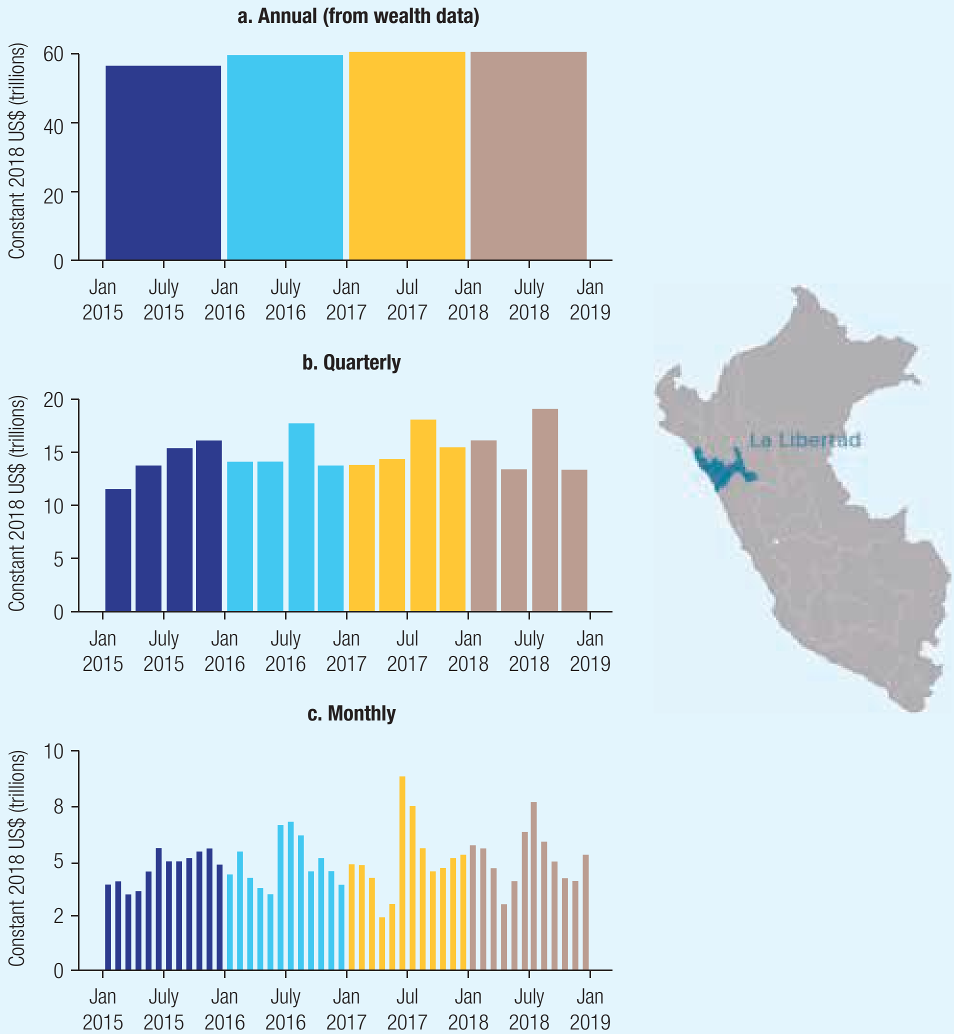
Statistical methods can introduce subannual variation and seasonal components into annual wealth data. This enables ESG scores to be based on momentum and recent performance. Measures such as year-on-year changes for every month and seasonal variations can shed light into otherwise neglected environmental degradations and improvements. Distributing country-level data over subnational entities allows ESG scores to incorporate regional discrepancies and trends. Extending the annual, country-level wealth data along spatial and temporal dimensions opens avenues for analyses that otherwise would not be possible.

Figure B13.3.1 depicts an example for how annual wealth data can be distributed over subannual frequencies and downscaled to subnational resolutions. The method is based on established benchmarking techniques (Di Fonzo and Marini 2012; Marini 2016). Machine learning and econometric methods have the ability to model relevant nonlinearities and make robust predictions for otherwise missing most recent values. These predictions are constructed with external validity and internal consistency in mind. Nonetheless, improving environmental indicators with new statistical methods raises novel challenges that require careful examination.

(continued on next page)

BOX 13.3 Extending Wealth Data with Satellite Imagery and Machine Learning *(continued)*

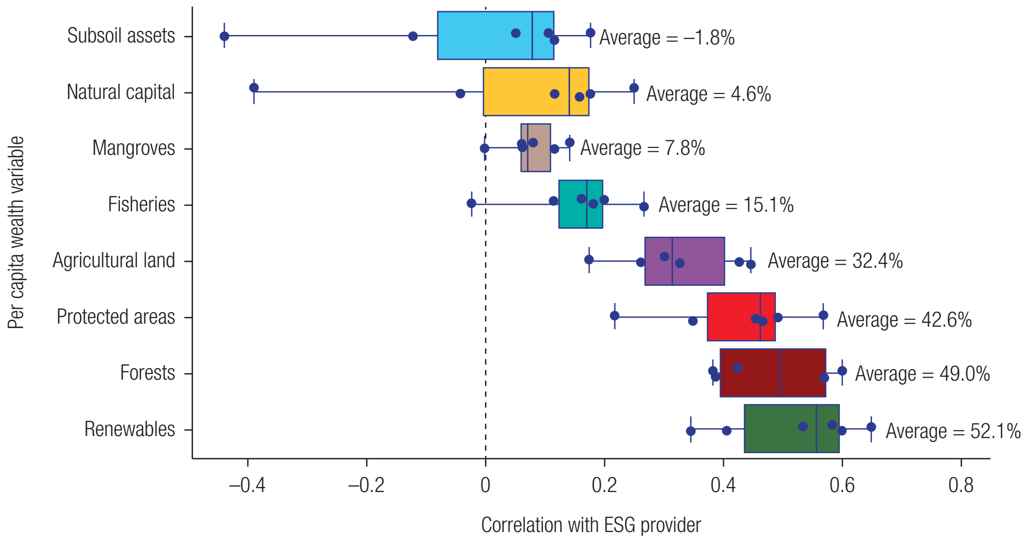
FIGURE B13.3.1 Extending Wealth Data along Temporal and Spatial Dimensions in La Libertad, Peru, 2015–19



Sources: European Space Agency, MIDAGRI (Ministry of Agriculture of Peru), BCRP (Central Reserve Bank of Peru), Instituto Geográfico Nacional; World Bank staff calculations.

Note: This figure illustrates how subannual numbers (quarterly or monthly) can be obtained from annual wealth statistics at the subnational level (first administrative level). The example here is calculated for La Libertad, in Peru, where annual cropland wealth is distributed throughout the year and country based on agricultural production data and agronomic satellite imagery. This benchmarking method ensures that the numbers are consistent: for example, quarterly numbers sum to annual numbers.

FIGURE 13.5 Correlation of Environmental ESG Scores with Natural Capital Components



Source: World Bank staff calculations.

Note: The box plots show the correlations between per capita natural capital (components) and environmental scores of six leading ESG providers. Each dot represents one ESG provider, the boxes demarcate the quartiles, and the whiskers locate the lowest and highest correlations. The term *ESG providers* refers to companies that provide ESG scores for incorporation into investment decisions. ESG providers differ from credit rating agencies, as the latter have an explicit mandate to assess an entity's ability to repay its debt. ESG = environmental, social, and governance.

Existing sovereign ESG scores reflect mostly renewable natural capital and are almost uncorrelated with nonrenewables. Figure 13.5 shows how the environmental scores of the six ESG providers studied in Gratcheva, Emery, and Wang (2020) are correlated with natural capital and its components. It turns out that when ESG providers construct their environmental pillars, they seem to focus comparatively more on renewable natural capital (52.1 percent average correlation) and its components: forests (49.0 percent), protected areas (42.6 percent), and agricultural land (32.4 percent). Subsoil assets, which contain nonrenewable fossil fuels and mineral assets, are almost uncorrelated with environmental scores (–1.8 percent). Thus, renewable natural capital already seems to capture the essence of what ESG providers consider to be environmental. This paves the way for wealth data to feature more prominently in ESG scores going forward.

Overcoming Wealth Data Constraints

Despite its suitability for informing sovereign ESG methodologies, wealth data have not been widely adopted by ESG providers. Wealth accounting and sovereign ESG share common goals for sustainable development. Due to their economic materiality, forward-looking perspective, and long history of consistently curated data, the wealth data also help to resolve the discussed challenges of current sovereign ESG scores. However, at the time of writing, only one of the seven major sovereign ESG providers examined has explicitly built its methodology around wealth data (Gratcheva, Emery, and Wang 2020).

A central hindrance to the incorporation of wealth data is their low frequency and high time-to-market. The release of the previous wealth report (Lange, Wodon, and Carey 2018) provided wealth data until 2014 at a five-year frequency. Conversations with practitioners revealed that data lags are one of the main obstacles for ESG providers. Social and governance pillar data had a three-year median lag, while environmental pillar data had a five-year median lag (Boitreaud et al. 2020). This data environment prompts users to apply imputation and interpolation methods to fill in missing data. Answering the call of practitioners, this newest iteration of the CWON extends these data until 2018 and increases the data frequency to annual. Although this still constitutes a data lag of three years, the annual frequency should greatly improve the data set's relevance for financial markets.

Advances in geospatial data pave the path for further improvements. With the recent developments in remote-sensing technologies, satellite imagery has become more accessible to the wider public. This data source has already been applied in various settings to quantify and verify environmental practices (WWF and World Bank 2020). The objective and globally consistent nature of earth observation data makes it an attractive choice for improving the existing data sets. Depending on the indicator, weather conditions, and geography, satellite mapping services can deliver reliable updates for up to weekly frequency. The European Space Agency is working to gather data on relevant environmental indicators for wealth data (ESA 2020).

Machine-learning methods can leverage geospatial data to improve existing wealth data. Statistical methods can be employed to downscale established wealth data to more relevant units. While wealth data can be spatially disaggregated over states and municipalities, the main benefit of machine-learning methods is to augment the temporal dimension. A promising application is to nowcast the most recent values that are otherwise missing.[4] Using the same toolbox, higher frequency earth observation data can also calculate quarterly or monthly wealth data from their annual figures. This introduces seasonal patterns, quantifies short-term impacts of disasters, and allows a timelier monitoring of deforestation trends or land degradation.

Conclusion

The philosophy behind wealth accounting largely overlaps with the goals of sovereign ESG scores and can help address some of the latter's shortcomings. Wealth data help to address three challenges of the current sovereign ESG scores. First, current environmental scores tend to focus on environmental materiality. However, the size of cropland in hectares alone may not be informative enough for policy makers. The wealth approach assigns an economically meaningful value that complements the raw environmental numbers. Second, current ESG scores are affected by the ingrained income bias, leading to possibly perverse investment incentives. The long history of wealth data allows practitioners to overcome the ingrained income bias by making it possible to focus on recent developments in environmental performance. Third, low correlations among the environmental scores of major ESG providers indicate a lack of consensus about what these scores should measure. Nonetheless, they seem to agree that renewable natural capital is part of the answer. A more explicit incorporation of natural capital may help to inform the development of future environmental scores.

Despite its suitable nature and promise for addressing the market's growing demand for high-quality environmental data, wealth accounting has not been fully utilized because of data constraints. The economic materiality, forward-looking perspective, and long history of consistently curated data suggest a close relationship between wealth data and sovereign ESG scores. However, the low frequency and high time-to-market of the wealth data have been a bottleneck to its wider adoption. This edition of the CWON introduces wealth data that addresses this bottleneck by raising the five-year update interval to annual. To foster the adoption of wealth data by financial market practitioners, the European Space Agency and various teams in the World Bank are working to increase the frequency of the data to subannual levels, lower the time-to-market, and scale the resolution up from countries to subnational entities. Key to this effort is the transparent combination of new remote-sensing data sources, robust statistical methods, and open dialogue with domain experts.

Notes

1. ESG integration is the practice of incorporating ESG-related information into investment decisions to help enhance risk-adjusted returns, regardless of whether a strategy has a sustainable mandate.
2. ESG scores are also sometimes called ESG ratings. This chapter uses "sovereign ESG scores" to distinguish them from "sovereign credit ratings," which measure the sovereign's creditworthiness. Sovereign ESG scores have emerged to complement assessment of sovereign creditworthiness.
3. The term *ESG providers* refers to companies that provide ESG scores for incorporation into investment decisions. ESG providers differ from credit rating agencies, as the latter have an explicit mandate to assess an entity's ability to repay its debt.
4. *Nowcasting* refers to predictions for the present or near future of variables that are usually updated on a lower frequency. Nowcasting is often used to obtain monthly GDP figures because official statistics are updated only quarterly.

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PART IV

New Developments in Measuring Wealth

14

Renewable Energy: Unaccounted Wealth of Nations

Robert Smith, Andrei Ilas, Javier Gustavo Inon, and Grzegorz Peszko

Main Messages

- Renewable energy represents an increasingly important yet still unaccounted part of the wealth of nations. The value of renewable energy assets already matches the value of fossil fuel energy in some countries, especially because of hydroelectricity, although as of 2017, solar and wind energy still rarely created economic rents.
- Countries should assign explicit value to renewable energy assets in national balance sheets. The System of National Accounts (SNA) and the System of Environmental-Economic Accounting (SEEA) should apply the same accounting approach to renewable energy assets they apply to other natural resource assets, such as fossil fuels.
- Policies and market regulations applied in the power systems determine whether and how much wealth renewable energy will generate. Subsidies to renewable and fossil fuel energy boost operators' profits without creating resource rents. Competitive electricity markets and carbon pricing can unlock wealth creation from solar and wind energy, eventually increasing their value above those of fossil fuel assets.

Introduction

To date, the natural capital accounts compiled in *The Changing Wealth of Nations* (CWON) have not included renewable energy assets. This is in part because few empirical studies of renewable energy asset values have been published (Rothman 2000) and also because the studies that have been undertaken have been hampered by data and methodological shortcomings. Furthermore, the measurement of renewable energy resources as assets has not been systematically addressed in the System of National Accounts 2008 (SNA) (EC et al. 2009), the accompanying System of Environmental-Economic Accounting–Central Framework (SEEA-CF) (UN et al. 2014), or the recent SEEA-Energy (UN 2019).

The lack of attention paid to the valuation of renewable energy assets is a concern. These assets—especially hydroelectric assets—are likely worth trillions of dollars worldwide today based on the estimates presented here and in the supporting technical report (Smith et al. 2021). Canada's hydroelectric resources alone may have been worth something on the order of US$456 billion (2018 US dollars) in 2017.[1] This would have made them more valuable than any other natural resource asset in Canada in that year (other than land), including the country's large fossil fuel reserves. Therefore, the failure to account for renewable energy assets as part of national wealth sends flawed signals to policy makers in many countries about the total national wealth and the contribution of natural capital to that wealth.

This chapter proposes a practical approach to valuation of renewable energy assets and compares it with the approaches recommended in the SNA and SEEA. It then tests this approach in an experimental effort to value selected renewable energy assets using data for several important renewable energy–producing countries. Based on the results, the chapter goes on to discuss how the experimental asset values presented here might be improved and expanded so that renewable energy assets might eventually be formally incorporated into the core natural capital accounts of the CWON and the revised SNA and SEEA standards.

Renewable Energy Resources as Assets in the SNA and SEEA-CF

In keeping with the general definitions of assets, the SNA and SEEA-CF recognize natural resources as assets only when ownership rights can be enforced over them. Ownership need not be private; natural resources owned collectively (for example, by a national government on behalf of its citizens) may also qualify as assets. Only those resources that generate economic benefits for their owners under (1) existing conditions of technology, knowledge, economic infrastructure, and prices or (2) conditions that can be reasonably expected to prevail in the immediate future (again, as revealed by market activity) are recognized as assets. Resources known to exist but, for whatever reason, not suitable for commercial exploitation do not qualify as assets in the SNA or the SEEA-CF.

The SNA says little on the treatment of renewable energy resources as assets. It simply notes that entities "over which no property rights can be exercised" do not qualify as assets, using the high seas and atmosphere as examples (EC et al. 2009, para 1.46; hereafter SNA and para. no.). This suggests that solar and wind resources would not be recognized as assets within the SNA, since they are closely linked to the atmosphere. What the SNA actually intends with respect to solar and wind resources is unclear, as neither is mentioned anywhere in the text. It is worth noting, however, that the SNA does recognize the radio spectrum used by telecommunications companies as a natural resource asset, reflecting the significant revenue governments earn by licensing its use (SNA para. 10.185). This is an important example of an entity that was previously considered to have no economic value and deemed impossible to “own” coming to meet both SNA tests of asset status through governments’ decisions to assert public ownership rights. The parallels with solar and wind energy resources are clear.

As with solar and wind resources, the SNA is silent on hydroelectric resources. However, it acknowledges that water “regularly” used for extraction can be considered a natural resource asset. Assuming that the temporary diversion of water through electric power turbines constitutes regular extraction, it is plausible that water in a hydroelectric power reservoir could be considered an asset in the SNA.

In contrast to the SNA, the SEEA-CF is explicit and quite detailed in its discussion of renewable energy resources as assets.[2] It argues that the value of these assets should be captured in the value of the land associated with renewable energy generation: “Opportunities to earn resource rent based on sources like wind, solar and geothermal should be expected to be reflected in the price of land” (UN et al. 2014, para 5.228; hereafter SEEA-CF and para. no.). Thus, according to the SEEA-CF, the asset value of wind electricity should be captured in the value of land where wind-powered electric turbines are sited. Similarly, the value of solar electricity assets should be reflected in the value of the associated land where solar panel arrays exist. In the case of hydro resources, the SEEA-CF argues that it is more relevant to consider the value in relation to the water used to generate the energy than to an area of land: the value of the water resource that will capture the value of the hydro asset according to the SEEA-CF.

While the SEEA-CF’s argument that changes in land value will arise “due to the scarcity of the sites used for energy generation” (SEEA-CF para. 5.310) has prima facie appeal, it does not appear to be plausible in many instances. The conditions in which the value of such assets could be expected to be reflected in the observed land values are limited to land-based production of solar and wind energy only and then only on land that (1) is privately owned, (2) has a positive economic value for something other than solar and/or wind energy production, and (3) is located in a country where renewable energy markets could be said to be in something like long-run equilibrium. It is questionable whether these conditions hold to any significant extent anywhere in the world. In many countries, solar and wind energy markets are nascent and do not yet approach the long-run equilibria in which private land values could be reasonably expected to reflect accurately the potential for renewable energy production. Some large-scale solar and wind energy production takes place offshore or in remote areas where there are not observed economic values in the absence of renewable energy production. Likewise, hydroelectric dams and generating stations are almost exclusively built on publicly owned waterways that have no economic value other than for hydroelectric production, irrigation, and flood control.

Given this context, it seems that application of the SEEA-CF's approach to the valuation of renewable energy assets risks missing much of the value of these increasingly important resources. Therefore, this chapter recommends applying the same approach to renewable energy assets as the SEEA-CF applies to other natural resource assets (SEEA-CF paras. 5.94–5.125). That is, the asset value of renewable energy resources should be explicitly calculated as the net present value of the future stream of rent attributable to the resources, and these values should be assigned to explicit renewable energy assets in national balance sheets. This would require the addition of a new category of natural resource assets to the SNA and SEEA-CF asset classifications (table 14.1).

The approach recommended here has two advantages. First, it ensures consistency in the accounting for all types of natural resource assets in the SNA and SEEA-CF. Second, it ensures that the full value of all renewable energy assets will be captured in national economic and environmental accounts.

A potential disadvantage of the approach is that it could lead to double counting of some renewable energy assets. It is acknowledged that there are instances where the price of land assets already measured in the national account will be influenced by the possibility (or reality) of using the land for renewable energy production. Adding explicit values for renewable energy assets on top of these existing values could lead to double counting, for example, by measuring the increase in value of a farmer's land from installation of a wind turbine and the asset value of the associated wind energy production. However, there are two reasons why the size of this double counting might be small. First, as argued earlier, the share of the total value of renewable energy assets that would be captured if the SEEA-CF approach were implemented is likely small. Second, and more

TABLE 14.1 Suggested Additions to the SNA and SEEA-CF Natural Resource Asset Classifications

SNA	SEEA-CF
Land	Mineral and energy resources
Mineral and energy reserves	Land
Renewable energy resources	Soil resources
Noncultivated biological resources	*Renewable energy resources*
Water resources	Timber resources
Other natural resources	Aquatic resources
Radio spectra	Other biological resources
Other	
	Water resources

Source: World Bank.

Note: Suggested additions are shown in italics. SEEA-CF = System of Environmental-Economic Accounting–Central Framework; SNA = System of National Accounts.

important, double counting would be all but eliminated in practice by the approach national accountants use in valuing land assets, in which land is valued as a residual after deducting the value of any other assets associated with it (Eurostat and OECD 2015).

Resource Rent and Renewable Energy Assets

The valuation of natural resource assets rests on the concept of resource rent, or the value that can be attributed to natural resources (as opposed to some other factor of production) in a production process. The evolving nature of renewable energy resource markets complicates analysis of the rent accruing to the resources, especially for the rapidly emerging solar and wind electricity generation.

Where rent arises from the use of renewable energy assets for the generation of electricity, it can be valued using the same approach as recommended in the SEEA-CF for the valuation of other natural resource assets. In this approach—called the residual value method (RVM)—rent is estimated as the difference between the annual revenues earned from the sale of the renewable electricity and the annual cost of its production, including normal returns to workers (wages) and entrepreneurs (return on produced capital) as well as an estimate of the consumption of produced capital. Any specific subsidies received by renewable electricity producers must be deducted from the value of sales, and any specific taxes must be added. While not without concerns from theoretical and practical points of view because of distortions in renewable energy markets, this seems to be the best choice available for valuation of renewable energy asset rents in the CWON.[3] Treatment of subsidies and taxes, as well as the choices of cost of capital and discount rates differentiate the value of renewable energy as part of the natural capital from the value of power plants as part of produced capital. The following section presents the results of the application of the RVM to the valuation of hydroelectric, solar, and wind resource assets in selected countries.

Valuation of Hydroelectric, Solar, and Wind Assets

The estimates presented here should be considered experimental and indicative, rather than definitive. They have been compiled in the interest of testing methodologies and evaluating data sources for eventual development of more refined and comprehensive estimates that could be incorporated into the core CWON natural capital accounts in the future.

Experimental estimates of hydroelectricity, solar electricity, and wind electricity assets were compiled for Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, the Russian Federation, Spain, Sweden, Turkey, the United Kingdom, and the United States.[4] Collectively, these 15 countries accounted for more than 70 percent of globally installed hydroelectric capacity, more than 86 percent of solar electricity capacity (photovoltaic and solar concentrator), and more than 87 percent of global wind electricity capacity (offshore and onshore) in 2017 according to the

International Renewable Energy Agency's Trends in Renewable Energy database.[5] The timeframe chosen for the analysis was 1990–2017 for consistency with the CWON natural capital accounts.

The formulas used to calculate renewable energy asset values are briefly described. It is essential here to address upfront the common confusion between the economic rent of a natural asset and the profit or cost-competitiveness of a renewable power plant operator. The formula shows why a solar or wind power plant can be commercially viable and cost-competitive with new thermal power plants, but the resource rent accruing to the renewable energy asset can still be negative. A more detailed technical description is available in the background CWON technical report (Smith et al. 2021).

Equation (14.1) expresses the version of the RVM used to estimate rent for renewable energy assets:

$$RR_t^i = TR_t^i - \mathrm{O\,\&\,}M_t^i - \left(rK_t^i + \partial^i\right), \tag{14.1}$$

where

RR_t^i = residual value estimate of the resource rent accruing to renewable energy asset i in year t,

TR_t^i = total revenue from sales of electricity generated from renewable energy asset i in year t net of any direct subsidies paid on generation,

$\mathrm{O\,\&\,}M_t^i$ = cost for labor, materials, fuel, and other supplies to operate and maintain the produced assets (wind turbines, solar panels, hydro dams, and so forth) used to generate electricity from renewable energy asset i in year t,

r = economywide average annual rate of returns to produced assets (a constant),

K_t^i = total value of produced assets used to generate electricity from renewable energy asset i in year t (for example, the value of wind turbines and other equipment required for the production of wind energy), and

∂^i = annual rate of depreciation of produced assets used to generate electricity from renewable energy asset i (a constant).

Once resource rent was estimated following equation (14.1), the next step was to determine the expected pattern of future rents. This required decisions on two parameters: the level of rent in future years and the number of years for which rent will flow. On the latter, it was assumed that rent will flow indefinitely because the sun will shine, the wind will blow, and the water will flow "permanently." On the former, the general approach in natural resource asset valuation is to assume that future rents will equal the rent observed in the time period in question. For example, a constant future stream of rent at 2017 levels would be assumed in the case of estimating the asset value for 2017. This is the approach used for other natural resource assets in the CWON and recommended in the SEEA-CF (SEEA-CF para. 5.133). It has been applied here.

With the current rent and its expected future pattern determined, the final step was to estimate the asset value as the discounted present value of future rent. Equation (14.2) expresses the present value calculation in algebraic notation specific to renewable energy assets:

$$V_t^i = \sum_{n=1}^{T} \frac{RR_t^i}{\left(1+r_g\right)^n}, \tag{14.2}$$

where

V_t^i = value of renewable energy asset i in year t,

RR_t^i = resource rent accruing to renewable energy asset i in year t (as defined in equation (14.1)),

T = renewable energy asset life in years,

n = future periods from 1 to T, and

r_g = economywide discount rate.

It is reasonable to assume that T in equation (14.2) is infinity. In this case, equation (14.2) reduces to the form shown in equation (14.3):

$$V_t^i = \frac{RR_t^i}{r_g} \tag{14.3}$$

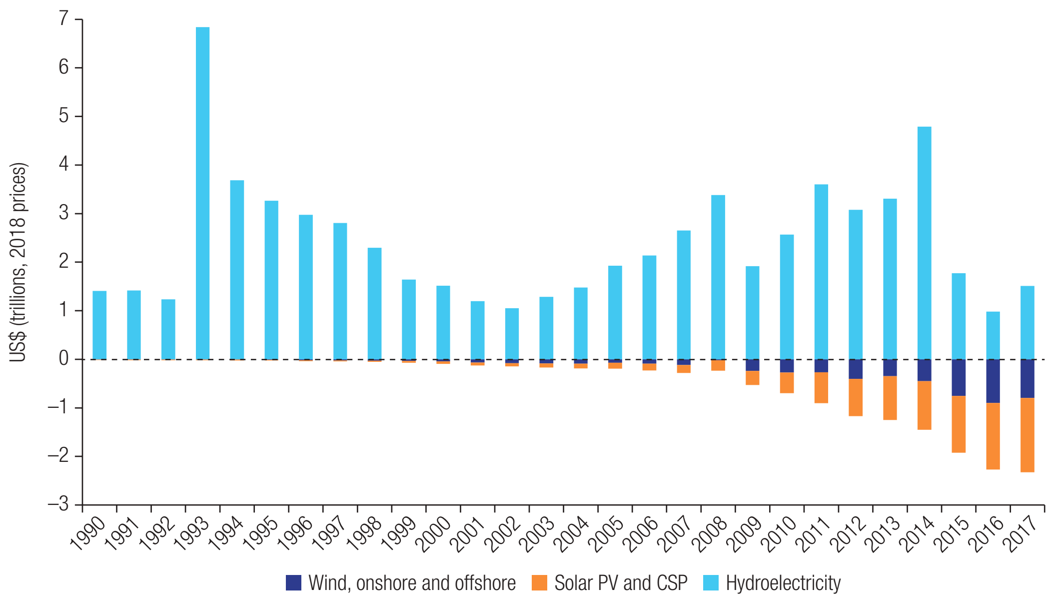
Equation (14.3) was applied to compile the time series of asset values. This required an estimate of the discount rate (r_g). In keeping with CWON practice in the valuation of other natural resource assets, a cross-country real (inflation-adjusted) discount rate of 4 percent was used.

Experimental Results of Values for Hydroelectric, Solar, and Wind Assets

Hydroelectricity assets have maintained value throughout the period, despite volatility (figure 14.1). Hydropower wealth matched the value of fossil fuel assets in some countries that were the most efficient in extracting value from their generous natural endowment, such as Brazil and Canada. Solar and wind energy assets are on track to generate wealth in the future as nascent, subsidized, but fast-growing industries with rapidly maturing technologies. Their total "negative"[6] asset value has been increasing rapidly (figure 14.1) following the surge in electricity production, but it is partly offset by wealth per unit of electricity produced approaching positive values (figure 14.2).

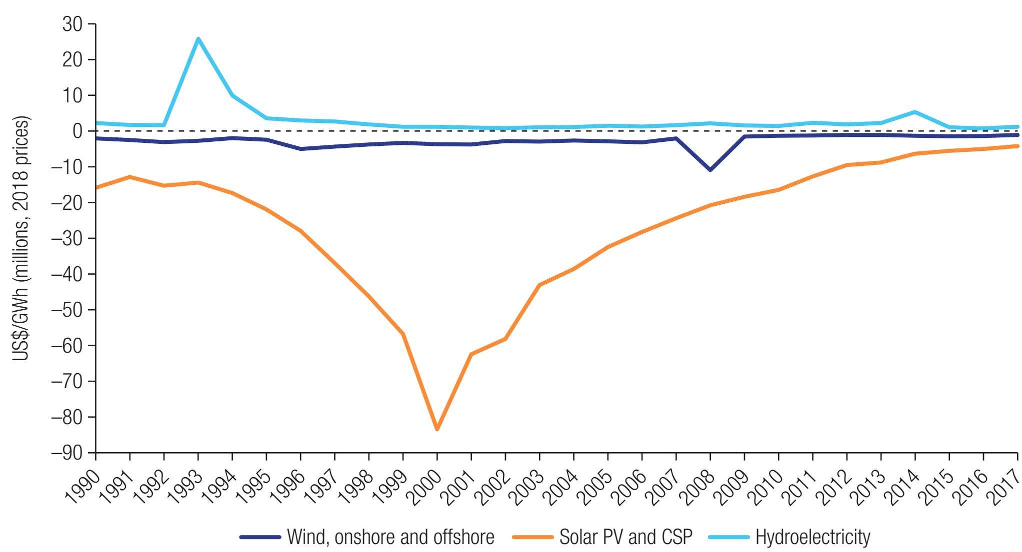
The market values of assets (based on the discounted future resource rents) should not be confused with the profits made by plant developers and operators. A wind or solar farm can be profitable and not generate positive value on wind and solar energy assets under current market conditions. Firms' profits include all specific subsidies, such as offtake prices that may be higher than market prices (feed-in tariffs and auctioned guaranteed tariffs), specific tax breaks, subsidies to project investment costs, and other provisions that reduce the risk and cost of capital specifically to renewable project developers. In the calculation of the market value of renewable energy rents (equation (14.1)), all these subsidies need to be

FIGURE 14.1 Renewable Energy Wealth in 15 Major Producing Countries, 1990–2017



Source: World Bank staff calculations.
Note: Negative values are illustrative only, portraying distance between present status and actual contribution to wealth. CSP = concentrated solar power; PV = photovoltaic.

FIGURE 14.2 Weighted Average Renewable Electricity Asset Value per GWh of Electricity Generated in 15 Major Producing Countries, 1990–2017



Source: World Bank staff calculations.
Note: Negative values are illustrative only, portraying distance between present status and actual contribution to wealth. CSP = concentrated solar power; GWh = gigawatt hour; PV = photovoltaic.

subtracted from the total revenues or added to the generation costs to the extent allowed by the availability of reliable data.[7] Figure 14.2 presents the time trends in weighted average of renewable electricity asset value per gigawatt hour (GWh) of electricity generated between 1990 and 2017,[8] showing that wind and solar electricity are yet to generate wealth, despite being profitable in many markets.

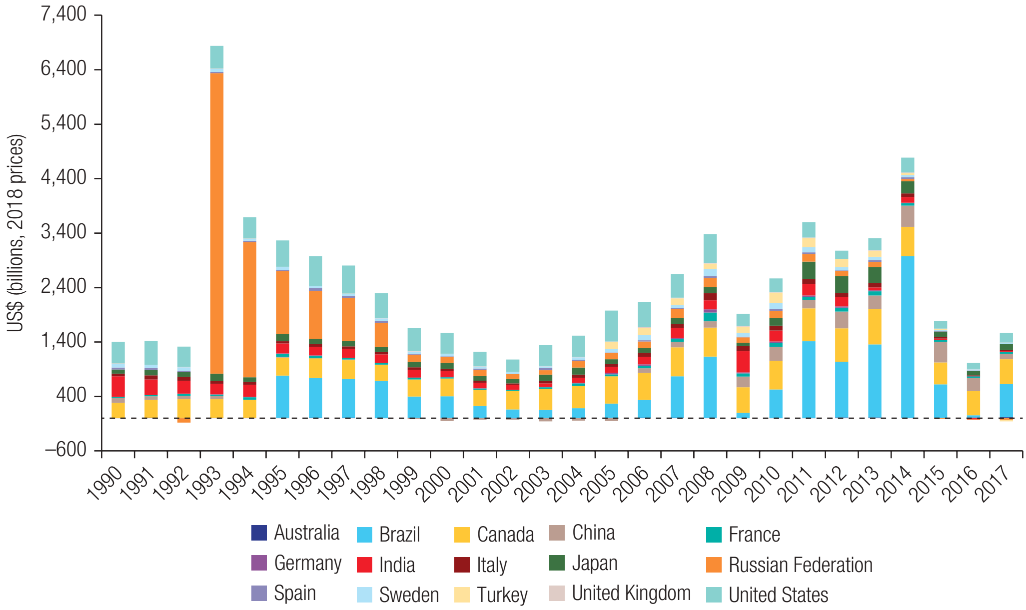
The total asset values divided by electricity generation permit meaningful international comparisons. The average unit of wealth created by hydropower has been positive and relatively stable throughout the period, reflecting the maturity of this technology. The 1993 and 2014 peaks are related to special events in Russia and Brazil, respectively. In 2017, the weighted average hydropower wealth per GWh of electricity generated was US$1.2 million.

Wind and solar power have not yet generated value in most of the countries studied; wind wealth has been consistently closer to positive values than solar, indicating its higher maturity. Unit wind wealth has been slowly approaching zero, with a dip in 2008 related to the economic crisis. In 2017, the wind power asset value averaged minus US$1.1 million per GWh in the 15 countries studied. Solar wealth is approaching positive values faster than wind. The generation costs of solar electricity and the level of subsidies have been steadily and rapidly falling. The change in the trend in the unit solar wealth around 2000 indicates a tipping point in solar power technology development, from research and development to the commercialization phase. Since then, the negative value of solar wealth per unit of electricity has been quickly approaching the inflection point where it will become positive, especially solar photovoltaic (PV).

Hydroelectricity Asset Values

Unsurprisingly, given the maturity of this technology, hydropower asset values are positive in nearly all years and countries (figure 14.3 and table 14.2). Asset values are "negative" only in Australia from 2001 to 2003, in China between 1999 and 2005, in India in 2016, in Russia in 1992 and 2015–17, and in Spain and Turkey in 2017. These few negative values and most of the observed volatility of hydropower asset value are explained by normal year-to-year variations in electricity prices, generation levels, and other market events. The negative values do not change the general conclusion that hydroelectric assets make substantial positive contributions to national wealth in the 15 countries studied, even without considering the non-electricity-related economic value of dams, such as for flood control and irrigation. Some variations of hydropower asset value are related to the volatility of local currencies. For example, the negative asset values in Australia from 2001 to 2003 are mainly due to the decline in the value of the Australian dollar versus the US dollar in combination with relatively low electricity spot prices. A sudden spike of hydropower wealth in Russia in 1993 is related to monetary reform and the temporary appreciation of the value of the ruble relative to the US dollar. A one-off surge in hydropower wealth in Brazil in 2014 was related not to an increase

FIGURE 14.3 Hydroelectric Asset Values in 15 Major Producing Countries, 1990–2017



Source: World Bank staff calculations.

in electricity generation but to a surge in offtake prices, which were pushed up by supply constraints due to droughts that coincided with increased demand due to the World Cup.

Many countries witnessed declines in the creation of wealth from hydroelectric resources over time, most notably China, India, Italy, Russia, Turkey, the United Kingdom, and the United States. Although there is no single explanation for this outcome, it is clear that the efficiency with which hydroelectric generating infrastructure (dams, reservoirs, and hydraulic turbines) was used played a role. For example, generation efficiency (or the capacity factor) in India declined more or less continually between 1990 and 2017, from 0.436 to 0.303.[9] The reason for this does not appear to be aging hydroelectric generating infrastructure, since only about 38 percent of Indian hydroelectric infrastructure had been installed by 1990 and major new investments were made in most years from 1990 to 2017. The decline may be climate related, since hydroelectric generation relies on rivers and reservoirs being full of water, which, in turn, relies on regular precipitation. For example, sudden falls in wealth creation by Brazil's hydropower in 2009 and 2015–16 were triggered by severe droughts related to El Niño events. Economic cycles and events also played a role. For example, the decline of Russia's hydroelectric assets into negative values beginning in 1992 was due to a significant decrease in the value of the Russian ruble versus the US dollar, just before monetary reform in 1993.

TABLE 14.2 Hydroelectric Asset Values: Market Resource Rent in 15 Major Producing Countries, 1990–2017

US$ (millions, 2018 prices)

Year	Australia	Brazil	Canada	China	France	Germany	India	Italy	Japan	Russian Federation	Spain	Sweden	Turkey	United Kingdom	United States
1990	7,054	a	284,299	86,579	20,532	3,054	374,834	52,272	74,335	a	34,871	64,822	a	9,520	402,004
1991	8,675	a	328,997	64,382	23,031	2,153	284,367	74,763	99,605	a	38,450	51,200	a	6,126	436,157
1992	6,879	a	342,995	58,149	39,689	5,189	233,044	75,786	82,371	(81,004)	22,982	68,373	a	8,410	372,702
1993	6,930	a	342,344	56,890	30,017	4,522	191,600	48,497	137,084	5,518,943	22,839	56,799	a	3,353	418,287
1994	7,879	a	327,267	5,620	45,617	6,591	222,524	52,890	84,878	2,479,004	26,497	38,799	a	5,336	384,861
1995	7,758	776,122	330,817	14,216	50,011	11,764	182,831	41,378	134,271	1,153,174	21,163	54,718	a	5,479	479,619
1996	8,219	732,529	359,564	2,574	41,363	10,900	151,162	56,343	96,475	881,722	50,163	33,877	a	2,385	548,954
1997	8,562	712,350	346,554	10,190	29,147	3,077	161,667	47,019	99,256	790,141	32,749	44,809	a	4,409	516,433
1998	3,040	684,526	293,846	5,328	27,455	3,074	155,294	47,071	87,475	445,708	31,602	50,288	a	7,025	453,711
1999	5,711	392,143	312,838	(14,535)	35,605	3,448	136,297	50,292	99,738	131,371	13,525	43,170	a	9,971	419,519
2000	6,377	399,153	326,424	(51,240)	21,290	2,172	109,802	37,958	114,030	109,000	10,412	39,848	a	7,981	382,641
2001	(556)	224,630	298,005	(23,439)	25,810	2,671	97,304	39,873	86,830	112,373	24,176	38,429	a	4,396	267,229
2002	(1,361)	164,228	336,765	(25,152)	18,810	3,734	84,762	34,321	78,755	87,223	4,336	31,502	a	6,902	227,937
2003	(197)	153,606	384,971	(56,247)	28,597	7,692	67,524	42,524	115,872	82,174	39,090	29,858	a	5,126	385,629
2004	2,349	182,112	406,037	(43,056)	49,360	11,596	89,538	61,316	129,236	113,840	29,522	42,368	a	10,437	391,281
2005	4,226	267,306	497,899	(50,671)	37,131	24,886	106,887	56,835	90,035	113,317	10,023	61,134	127,066	11,252	567,297
2006	9,818	325,924	495,239	86,800	43,570	29,898	131,008	82,762	84,676	121,284	22,249	92,345	135,115	13,012	462,677
2007	9,719	760,358	530,277	105,917	51,098	20,456	176,485	70,638	113,855	167,917	14,142	56,769	122,731	16,028	433,227
2008	3,546	1,127,657	533,646	115,238	162,693	57,290	165,390	131,599	111,429	165,614	34,736	126,622	104,052	14,217	525,672
2009	1,482	96,104	473,535	192,917	58,261	17,798	389,503	93,472	63,199	101,186	9,456	70,271	116,789	10,175	224,429
2010	743	528,252	526,522	255,486	74,751	25,301	200,195	89,605	136,085	137,717	28,489	114,794	188,269	5,652	256,481
2011	2,672	1,410,780	605,773	153,526	54,894	25,115	210,589	92,377	321,222	137,521	30,298	95,301	166,651	10,930	281,723
2012	12,839	1,025,907	610,365	311,147	69,664	22,600	171,473	75,806	307,223	97,603	9,395	62,743	142,116	8,584	148,512
2013	14,675	1,343,174	648,911	246,886	76,590	18,605	55,641	82,730	289,658	95,001	31,761	61,182	113,051	8,634	218,585
2014	7,029	2,968,652	540,629	387,374	46,785	8,909	99,469	71,127	222,140	38,978	31,899	45,489	34,721	8,483	275,666
2015	6,755	616,764	402,834	378,745	31,177	1,853	23,416	33,011	98,156	(12,684)	12,256	17,391	20,787	5,255	135,018
2016	16,636	36,594	446,223	239,325	30,953	1,303	(22,298)	16,830	78,946	(11,169)	12,289	21,520	589	2,343	113,591
2017	18,092	607,435	456,168	100,386	35,654	5,878	6,124	22,227	110,841	(31,393)	(650)	27,572	(25,475)	2,690	172,552

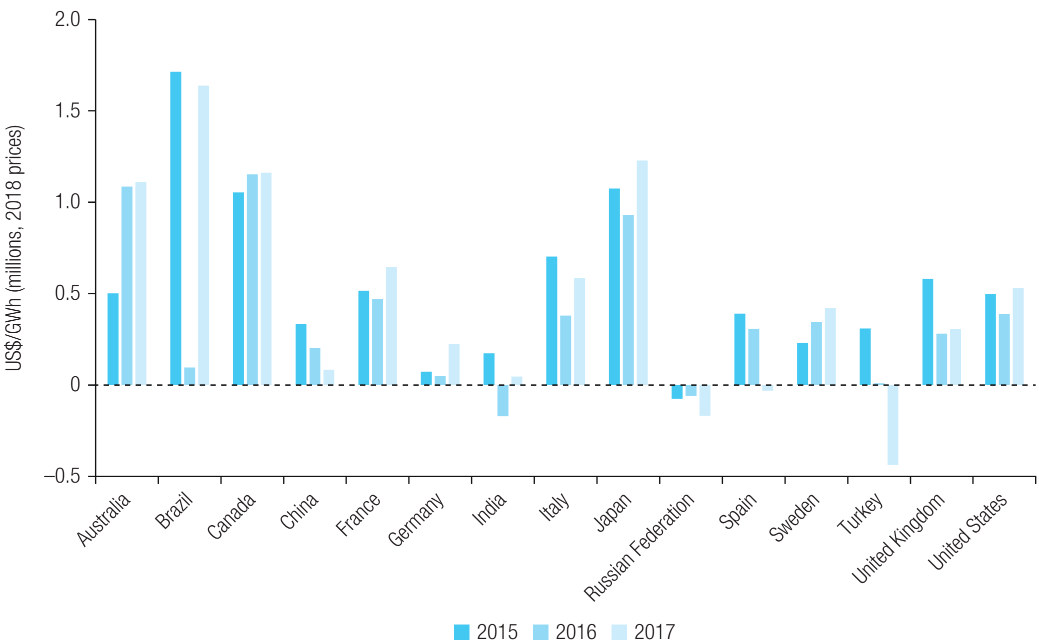
Source: World Bank staff calculations.

Note: Figures in parentheses are negative values. Technically, an asset cannot have a negative value, but here negative values show “how far” hydroelectric assets are from making positive contributions to national wealth.

a. Years for which production occurred but values are not shown because of currency changes.

The wealth that countries create from 1 GWh of their renewable energy resources is a measure of their relative success in using their natural resource base. Figure 14.4 presents such unit hydroelectric wealth for the last three years in the period. Brazil was the most successful in converting hydroelectric resources into well-being in 2017, creating more than US$1.6 million in asset value for every GWh of hydroelectricity produced,[10] followed by Japan, Canada, and Australia, creating US$1.1 million to US$1.2 million in wealth per GWh. At the other end of the spectrum, Russia was the only country in the sample that created no wealth from hydropower per unit of generation in the three consecutive years. Spain and Turkey extracted no value in 2017 due to severe droughts. India had no wealth in hydropower in 2016 and a very small unit value in 2017. Falling prices for hydroelectricity played a role in declining unit wealth.[11] This was the main reason why wealth per GWh fell from US$1.4 million in 1990 to just US$531,000 in the United States in 2017. Falling offtake electricity prices also played a role in declining unit wealth in Italy, Spain, Turkey,[12] and the United Kingdom. Rising produced-capital costs were also an important factor in declining unit hydropower wealth in several countries, most notably China and India, where produced-capital costs per GWh rose by 110 and 183 percent, respectively, over the period. This was the result of very large and expensive investments in new generating capacity in both countries.

FIGURE 14.4 Hydroelectricity Asset Value per GWh of Electricity Generated in 15 Major Producing Countries, 2015–17



Source: World Bank staff calculations.
Note: Technically, an asset cannot have a negative value, but here negative numbers show “how far” hydroelectric assets are from making positive contributions to national wealth. GWh = gigawatt hour.

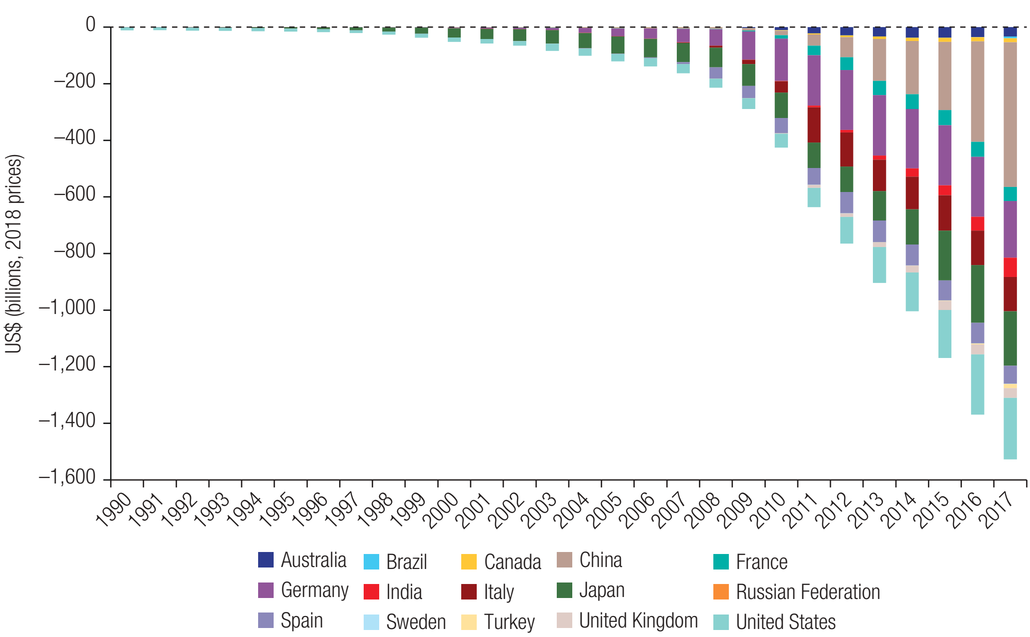
Chinese-installed hydroelectric capacity increased almost tenfold over the period, while in India it nearly tripled.

Solar Electricity Asset Values

Given that generation costs were declining faster than subsidies, wind and solar power investments became increasingly profitable in most markets, triggering exponential growth of capacity additions and electricity generation.[13] This rapid increase in generation multiplied by negative (although increasing) values of rents per megawatt hour of electricity generated led to a buildup of large, temporarily negative values of solar and wind energy assets.

Figures 14.5 and 14.6 and table 14.3 present the experimental results for the market value of combined solar photovoltaic and concentrated solar power (CSP) electricity assets. Solar electricity assets have not yet created value in any country in this sample or in any year until 2017. This is not unexpected, given the relative immaturity of the solar electricity sector, its generally high-cost structure, and the significant subsidies paid by governments to support its development in the past two decades. Four countries produced electricity from solar PV and CSP assets (China, India, Spain, and the United States). In all of them, PV assets were closer to positive asset values than CSP.

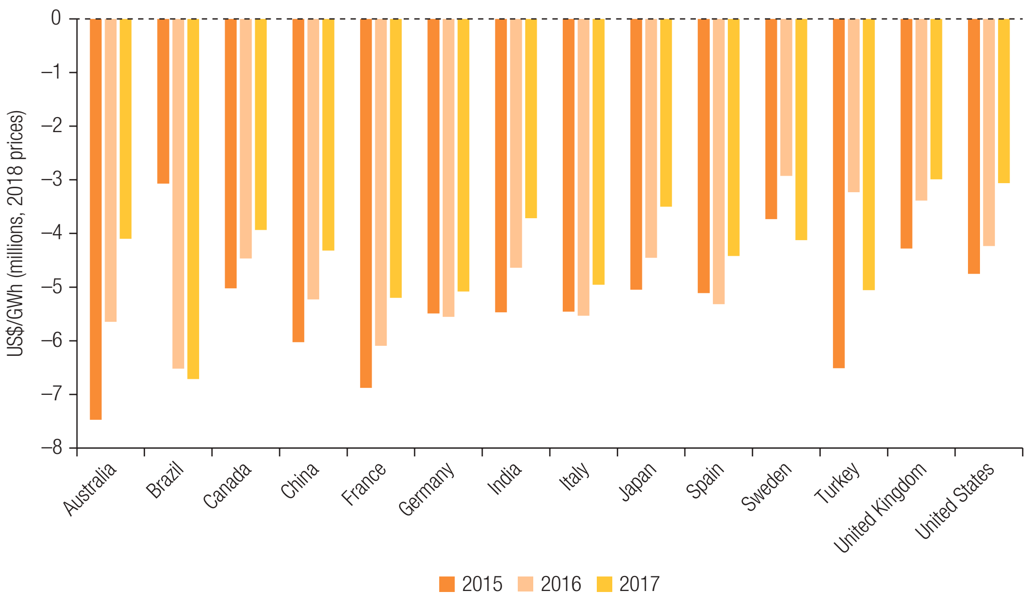
FIGURE 14.5 Combined Solar PV and CSP Asset Values in 15 Major Producing Countries, 1990–2017



Source: World Bank staff calculations.

Note: Technically, an asset cannot have a negative value, but here negative numbers show "how far" solar assets are from making positive contributions to national wealth. The 1990–2000 results are not shown for most countries, because their values were negligible, confirming the nascent industry argument. CSP = concentrated solar power; PV = photovoltaic.

FIGURE 14.6 Solar Asset Value per GWh of Electricity Generated in 14 Major Producing Countries, 2015–17



Source: World Bank staff calculations.
Note: No data were available for the Russian Federation. Technically, an asset cannot have a negative value, but here negative numbers show "how far" solar assets are from making positive contributions to national wealth. GWh = gigawatt hour.

Wind Electricity Asset Values

The market value of combined (onshore and offshore) wind electricity assets shows no wealth creation most of the time but positive asset value at least for some years and countries (figure 14.7 and table 14.4). Onshore wind assets had positive market values in Turkey from 2005 to 2014, in the United Kingdom in 10 of the 17 years from 1998 to 2015, and for a handful of years (between one and five) in Australia, Brazil, Canada, France, Germany, India, Italy, Spain, Turkey, and the United States. The positive wind asset values in Turkey over 2005–14 could be explained by the power market design and low renewable subsidies. During this period, renewable power producers were allowed to opt out of moderate feed-in tariffs and sell electricity at the balancing market, where prices were higher and subsidies were not needed. As with solar assets, lack of wealth creation is expected, given the relative immaturity of the sector and its high, although decreasing, degree of subsidization.

On a per GWh basis, Spain, Australia and Brazil were closest to unit wealth creation from their wind resources in 2017 (figure 14.8). China, India, Germany, and Japan lag behind other countries in efficiency of wealth creation from a unit of wind electricity. This may be related to the investment boom in this period.

TABLE 14.3 Combined Solar PV and CSP Electricity Asset Values: Market Resource Rent in 14 Major Producing Countries,1990–2017

US$ (millions, 2018 prices)

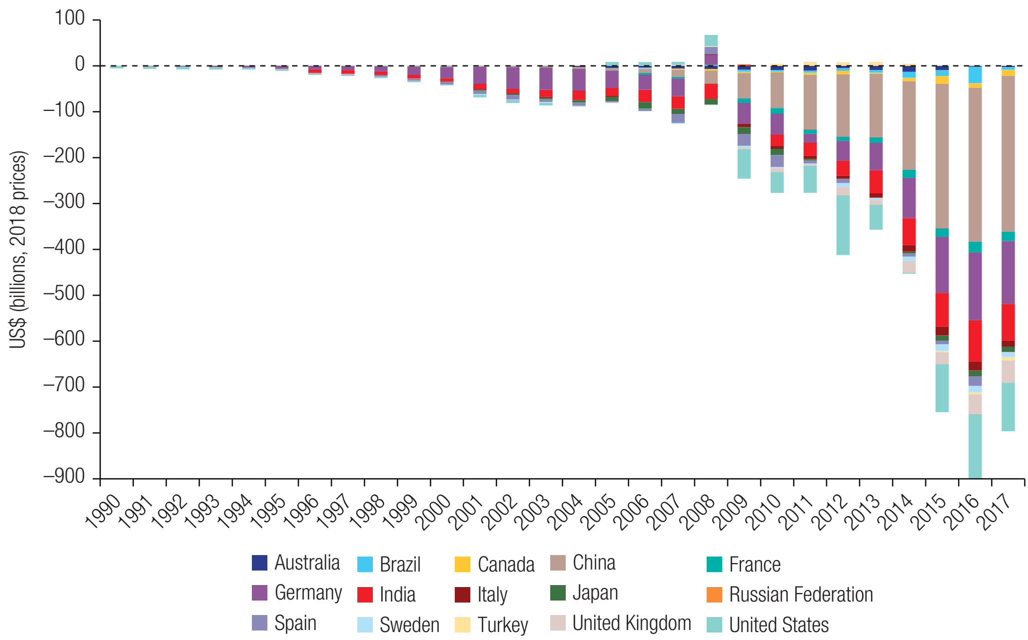
Year	Australia	Brazil	Canada	China	France	Germany	India	Italy	Japan	Spain	Sweden	Turkey	United Kingdom	United States
1990	..	..	..	..	..	..	..	(84)	(598)	(63)	..	..	..	(10,816)
1991	..	..	..	..	..	(39)	..	(102)	(555)	(83)	..	..	..	(10,181)
1992	..	..	(25)	..	(43)	(115)	..	(159)	(1,213)	(77)	..	..	..	(11,333)
1993	(111)	..	(23)	..	(42)	(172)	..	(248)	(2,017)	(105)	..	..	..	(10,794)
1994	(139)	..	(50)	..	(40)	(222)	..	(287)	(3,056)	(126)	..	..	..	(10,509)
1995	(165)	..	(47)	..	(39)	(333)	..	(320)	(4,491)	(137)	..	..	..	(10,314)
1996	(189)	..	(70)	..	(60)	(517)	..	(305)	(6,547)	(135)	..	..	..	(10,017)
1997	(231)	..	(94)	..	(79)	(775)	..	(318)	(9,653)	(133)	..	..	..	(9,930)
1998	(274)	..	(115)	..	(98)	(974)	..	(329)	(14,181)	(178)	..	..	..	(10,500)
1999	(325)	..	(136)	..	(117)	(1,264)	..	(316)	(21,232)	(168)	..	..	..	(14,082)
2000	(343)	..	(155)	(1,253)	(133)	(2,081)	..	(331)	(32,442)	(347)	(42)	..	..	(15,374)
2001	(412)	..	(197)	(1,354)	(127)	(3,591)	(206)	(342)	(35,590)	(407)	(40)	..	(22)	(15,707)
2002	(481)	..	(209)	(1,853)	(144)	(4,591)	(236)	(373)	(41,005)	(481)	(38)	..	(39)	(16,203)
2003	(543)	..	(237)	(2,054)	(159)	(7,133)	(259)	(442)	(47,311)	(560)	(50)	..	(76)	(25,462)
2004	(628)	..	(277)	(2,220)	(195)	(16,633)	(248)	(520)	(54,137)	(739)	(48)	..	(110)	(25,656)
2005	(680)	..	(312)	(3,611)	(226)	(27,483)	(332)	(555)	(60,490)	(997)	(46)	(18)	(155)	(26,068)
2006	(745)	..	(353)	(3,851)	(252)	(35,013)	(325)	(714)	(65,999)	(2,310)	(54)	(21)	(202)	(28,895)
2007	(801)	..	(402)	(4,416)	(418)	(47,769)	(650)	(1,693)	(67,336)	(6,887)	(64)	(20)	(256)	(32,468)
2008	(913)	..	(464)	(5,115)	(1,123)	(57,617)	(680)	(6,635)	(69,526)	(39,638)	(77)	(22)	(323)	(32,202)
2009	(3,559)	..	(1,057)	(7,327)	(3,649)	(99,024)	(779)	(15,077)	(77,597)	(42,537)	(82)	(23)	(371)	(38,458)
2010	(10,792)	(46)	(2,106)	(15,407)	(12,353)	(148,965)	(1,256)	(40,448)	(89,652)	(54,529)	(87)	(23)	(1,234)	(48,697)
2011	(22,067)	(37)	(4,278)	(39,313)	(33,793)	(177,600)	(6,470)	(124,548)	(89,586)	(59,729)	(89)	(26)	(10,445)	(68,378)
2012	(29,325)	(46)	(6,223)	(70,813)	(45,427)	(211,279)	(9,142)	(120,369)	(90,102)	(75,323)	(148)	(42)	(12,651)	(94,206)
2013	(32,987)	(67)	(8,873)	(148,282)	(50,103)	(213,723)	(14,462)	(110,962)	(103,880)	(77,016)	(200)	(59)	(16,660)	(126,557)
2014	(37,548)	(127)	(11,619)	(187,607)	(52,307)	(210,213)	(28,722)	(115,419)	(124,659)	(73,993)	(251)	(235)	(24,138)	(137,069)
2015	(37,502)	(242)	(14,542)	(241,020)	(53,320)	(212,666)	(34,671)	(125,230)	(175,758)	(70,834)	(362)	(1,263)	(32,250)	(169,379)
2016	(35,033)	(905)	(14,582)	(354,959)	(52,764)	(211,641)	(48,906)	(122,317)	(203,767)	(72,559)	(418)	(3,368)	(35,277)	(213,072)
2017	(33,073)	(6,696)	(14,063)	(510,658)	(49,776)	(200,157)	(68,675)	(120,764)	(192,737)	(63,630)	(948)	(14,613)	(34,461)	(217,364)

Source: World Bank staff calculations.

Note: Figures in parentheses are negative values. Technically, an asset cannot have a negative value, but here negative values show “how far” solar assets are from making positive contributions to national wealth.

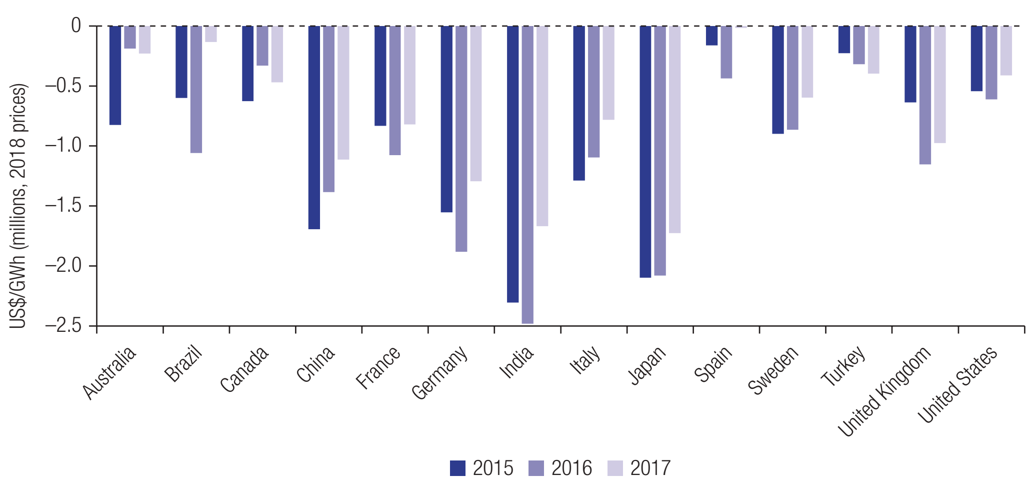
.. = negligible value.

FIGURE 14.7 Combined Onshore and Offshore Wind Electricity Asset Values in 15 Major Producing Countries, 1990–2017



Source: World Bank staff calculations.
Note: Technically, an asset cannot have a negative value, but here negative numbers show “how far” wind assets are from making positive contributions to national wealth.

FIGURE 14.8 Wind Asset Value per GWh of Electricity Generated in 14 Major Producing Countries, 2015–17



Source: World Bank staff calculations.
Note: No data were available for the Russian Federation. Technically, an asset cannot have a negative value, but here negative numbers show “how far” wind assets are from making positive contributions to national wealth. GWh = gigawatt hour.

TABLE 14.4 Combined Onshore and Offshore Wind Electricity Asset Values: Market Resource Rent in 14 Major Producing Countries, 1990–2017

US$ (millions, 2018 prices)

Year	Australia	Brazil	Canada	China	France	Germany	India	Italy	Japan	Spain	Sweden	Turkey	United Kingdom	United States
1990	..	..	..	..	..	..	(228)	(8)	..	(3)	..	..	(55)	(5,413)
1991	..	..	..	..	(5)	(1,005)	(263)	(12)	..	(4)	..	..	(78)	(5,512)
1992	..	..	(19)	..	(5)	(1,671)	(254)	(35)	..	(3)	..	..	(285)	(5,375)
1993	..	..	(9)	..	(19)	(2,333)	(359)	(107)	(6)	(23)	..	..	(469)	(4,781)
1994	(12)	..	(17)	..	(15)	(3,539)	(284)	(117)	(16)	31	..	..	(319)	(3,686)
1995	(8)	..	(14)	..	(14)	(5,595)	(792)	(115)	(23)	(101)	..	..	(440)	(3,860)
1996	(7)	..	(11)	(189)	(28)	(7,284)	(7,849)	(131)	(35)	(662)	..	..	(424)	(3,171)
1997	(7)	..	(9)	(556)	(29)	(8,498)	(7,916)	(456)	(47)	(1,193)	..	..	(410)	(3,141)
1998	(15)	..	(12)	(1,064)	(64)	(10,668)	(8,200)	(488)	(97)	(2,563)	..	..	82	(3,835)
1999	(49)	..	(145)	(1,644)	(61)	(17,048)	(8,227)	(542)	(394)	(4,432)	..	..	(92)	(2,938)
2000	(204)	(231)	(82)	(2,122)	(132)	(24,151)	(6,803)	(1,006)	(1,101)	(5,077)	..	..	(187)	(1,591)
2001	(473)	(197)	(135)	(2,147)	(193)	(35,749)	(12,048)	(1,521)	(1,762)	(7,922)	(1,178)	..	(539)	(5,273)
2002	(592)	(169)	(142)	(2,357)	(355)	(46,472)	(10,491)	(1,509)	(2,467)	(9,547)	(1,110)	..	30	(6,703)
2003	(989)	(185)	(101)	(2,598)	(481)	(48,464)	(15,466)	(1,327)	(3,895)	(6,241)	(1,110)	..	(758)	(5,349)
2004	(2,405)	(172)	(286)	(3,445)	(666)	(47,216)	(19,710)	(1,298)	(5,312)	(7,129)	(1,057)	..	33	(851)
2005	(5,016)	(158)	77	(4,659)	(1,506)	(36,140)	(18,391)	(1,932)	(8,930)	(3,087)	(1,051)	125	(651)	8,458
2006	(4,048)	(1,567)	(1,546)	(8,478)	(2,991)	(33,483)	(26,753)	159	(14,289)	(5,338)	(506)	120	874	7,168
2007	(5,848)	(219)	(2,358)	(15,518)	(3,244)	(39,011)	(26,817)	(342)	(11,404)	(19,709)	(1,963)	697	1,842	6,247
2008	(7,051)	1,171	(3,277)	(28,377)	948	21,458	(33,679)	1,953	(12,460)	15,637	(598)	1,601	(387)	24,482
2009	(8,539)	(3,815)	(3,589)	(54,724)	(9,269)	(46,329)	2,808	(7,167)	(14,888)	(26,013)	(3,321)	1,446	(3,926)	(64,325)
2010	(9,081)	(3,285)	(1,931)	(77,712)	(11,504)	(45,872)	(25,284)	(6,270)	(13,542)	(26,223)	(2,047)	4,425	(8,708)	(45,704)
2011	(9,994)	(4,855)	(4,789)	(119,074)	(9,340)	(18,719)	(28,971)	(7,578)	(2,843)	(6,779)	(1,553)	8,638	(3,436)	(58,851)
2012	(5,338)	(5,612)	(7,581)	(135,633)	(9,301)	(42,810)	(32,874)	(6,259)	(1,103)	(9,253)	(8,506)	7,960	(17,806)	(130,330)
2013	(9,362)	(5,433)	(2,622)	(138,209)	(11,411)	(60,457)	(50,592)	(8,665)	(840)	(227)	(4,706)	8,853	(10,011)	(54,470)
2014	(13,068)	(12,212)	(8,195)	(193,262)	(17,469)	(87,643)	(59,240)	(13,268)	(5,024)	(6,445)	(9,707)	4,547	(25,026)	(2,436)
2015	(9,455)	(12,953)	(16,588)	(315,112)	(17,741)	(123,024)	(73,472)	(19,125)	(11,703)	(7,942)	(14,606)	(2,635)	(25,657)	(104,795)
2016	(2,293)	(35,441)	(10,070)	(335,419)	(23,098)	(147,915)	(90,010)	(19,379)	(12,828)	(21,351)	(13,390)	(4,929)	(42,967)	(140,528)
2017	(2,891)	(5,662)	(13,496)	(339,657)	(20,273)	(136,807)	(79,513)	(13,877)	(11,204)	(857)	(10,517)	(7,116)	(48,771)	(105,896)

Source: World Bank staff calculations.

Note: Figures in parentheses are negative values. Technically, an asset cannot have a negative value, but here negative values show "how far" wind assets are from making positive contributions to national wealth.

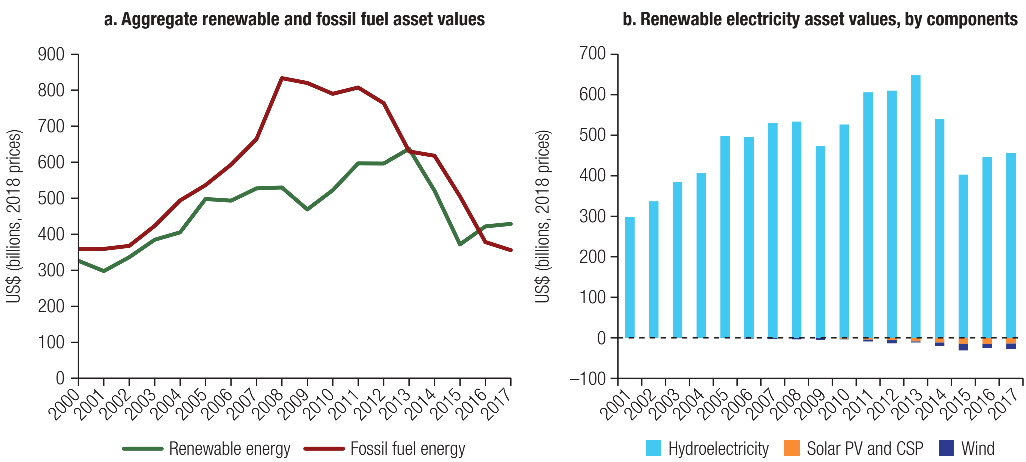
.. = negligible value.

Renewable versus Nonrenewable Energy Asset Values

The value of renewable energy assets has recently exceeded the value of fossil fuels in 2 of the 15 countries—Brazil and Canada. These two countries share some common features. Both are generously endowed in hydroelectric resources and fossil fuel reserves, and both are quite efficient in extracting value from water resources. And both countries have relatively few wind and solar power plants in operation. Based on official Canadian statistics,[14] the US$456 billion value of Canada's hydroelectric assets in 2017 would make these assets the second-most valuable natural resource asset (after land) in that year, with a value substantially greater than that of the country's vast fossil fuel assets (figure 14.9). Even in 2008, when Canada's fossil fuel assets experienced their peak value (Can$1.1 trillion), hydroelectric assets were worth nearly half as much as fossil fuels based on the experimental results here.

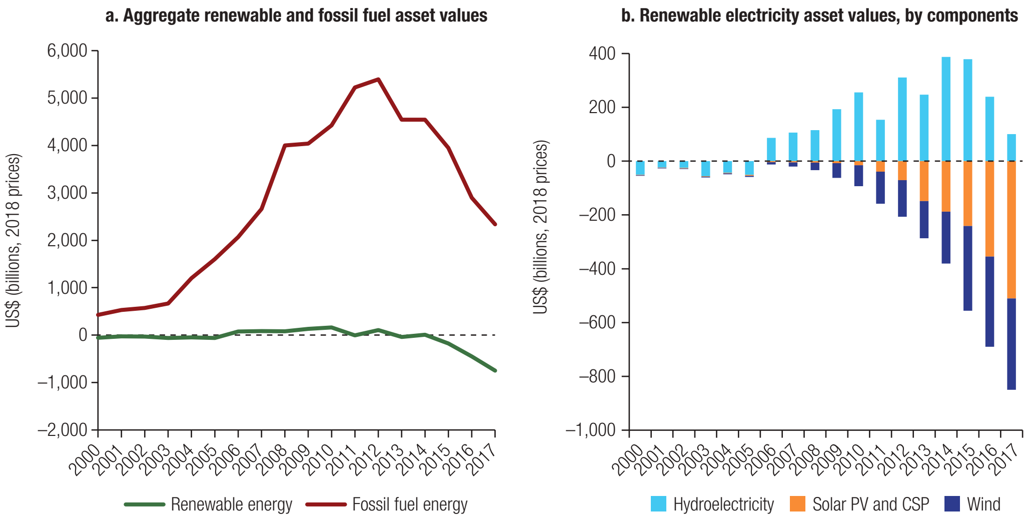
In the case of China, the results suggest that that hydroelectric resources were worth a small fraction of fossil fuel assets (figure 14.10). In 2017 hydropower generated over US$100 billion in wealth to the country, while the combined value of fuel reserves reached US$2.3 trillion, of which over half was accounted for by coal. Unlike Canada, China has been accumulating massive solar and wind energy capacity in recent years. Due to the generation volume effect, their aggregate negative asset value was rapidly increasing to more than minus US$800 billion, despite unit asset values quickly approaching the inflection threshold. Going forward, it can be expected that the value of fossil fuel assets will continue to fall, while

FIGURE 14.9 Evolution of Renewable and Nonrenewable Energy Asset Values in Canada, 2000–2017



Sources: World Bank staff calculations.
Note: Panel a illustrates the evolution of aggregate renewable and nonrenewable (fossil fuel) energy asset values. Panel b breaks down the value of renewable electricity asset value into its components. Results are shown for short time series only since 2000 for clarity. Technically, an asset cannot have a negative value, but in panel b negative numbers show "how far" renewable energy assets are from making positive contributions to national wealth. CSP = concentrated solar power; PV = photovoltaic.

FIGURE 14.10 Evolution of Renewable and Nonrenewable Energy Asset Values in China, 2000–2017



Sources: World Bank staff calculations.
Note: Panel a illustrates the evolution of aggregated renewable and nonrenewable (fossil fuel) energy asset values. Panel b breaks down the value of renewable electricity asset value into its components. Results are shown for short time series only since 2000 for clarity. Technically, an asset cannot have a negative value, but here negative numbers show "how far" renewable energy assets are from making positive contributions to national wealth. CSP = concentrated solar power; PV = photovoltaic.

the volume of renewable energy generation will continue increasing, flipping to positive asset values depending on the future development of the power market reforms that were started in 2015, especially the gradual phasing out of guaranteed operating hours and fixed offtake prices for coal power plants, and depending on the future of carbon pricing.

Future Trends in Renewable Electricity Asset Values

Simple extrapolation of past trends can be misleading about the tipping points for value creation by variable renewable energy. Simple projections of market values of wind assets (especially onshore) suggest that they could flip positive earlier than for solar PV—between 2018 and 2025 in most of the countries studied.[15] For solar PV assets, the first year in which they will have permanent positive values may lie beyond 2026 for most countries and even beyond 2035 for some.[16] But in the world going through a disruptive transformation, simple extrapolation of past trends or even more sophisticated econometric modeling is not a good tool to predict the future. Competitive electricity markets where low-cost renewable energy would be allowed to simply displace existing thermal power plants are the exception rather than a rule, especially in developing countries (Foster and Rana 2020). The country-specific simulations conducted for this chapter show that institutions and policies can slow or accelerate wealth creation from solar and wind energy.

This section shows simulations of potential future value of renewable energy assets conducted for South Africa and Angola.[17] The goal is not to predict the future, but to simulate policy conditions, under which the asset value of renewable energy can match the value of fossil fuel wealth. Wealth created by solar, wind, and hydro energy is a net present value (NPV) (at 4 percent discount) of resource rents calculated according to RVM as the gross revenues minus specific subsidies, minus full operations and maintenance costs of producing electricity, minus depreciation, and minus return on produced capital. The renewable wealth represents net return on nature's services rather than a net return on investments in power plants and transmission lines. It should be compared not to lifetime profits of plant developers but to the NPV of other resource rents, such as those attributed to oil, coal, and gas reserves. The distinction between wealth creation from natural capital (water, wind, and solar energy) and profit creation by produced capital (infrastructure that harnesses this energy) is new, and hence sometimes initially confusing to people familiar with the trends that the generation costs of new solar and wind power plants are often competitive with new thermal plants. The main reason for difference are subsidies or favorable financing structures (in the form of guaranteed offtake prices, concessional finance, special tariffs, and so forth) that can make renewable energy plants profitable to operators but would not change the resource rents and hence "returns on nature's services." Other reasons are illustrated with simulation results.

The method for valuation of renewable electricity rents and asset values are based on the SNA and SEEA approach used by the CWON. The model was run with the expansion to the power systems until 2040, following a projection of demand growth, available technologies for new power plants, and calibrated to market conditions and constraints specific to the individual power systems. For each system and model scenario, two headline indicators were calculated: (1) total value of renewable energy asset per year t for each power plant i in US$ millions (V_t^i) and (2) asset value per megawatt hour of electricity generated ($V_{gen\,t}^i$).

Exploratory "what-if?" scenarios represent hypothetical possible future evolutions of alternative regulatory environments for renewable energy in Angola and South Africa. Four exploratory policy scenarios of the power system expansion trajectories were designed as combinations of two policy instruments: cost-competitive electricity market design and carbon pricing (table 14.5). Scenarios were designed with purely hypothetical assumptions to represent a range of potential impacts of

TABLE 14.5 Climate and Energy Policy Scenarios for the Power System Expansion Models

	Retirement of existing plants not allowed	Retirement of existing plants (stranded thermal assets) allowed
No carbon pricing	Noncompetitive/brown	Competitive/brown
Carbon pricing	Noncompetitive/green	Competitive/green

Source: World Bank.

alternative policy reforms on the ability of renewable energy resources to create resource rents to a host country, and do not aim at forecasting or recommending any particular policy in these countries.

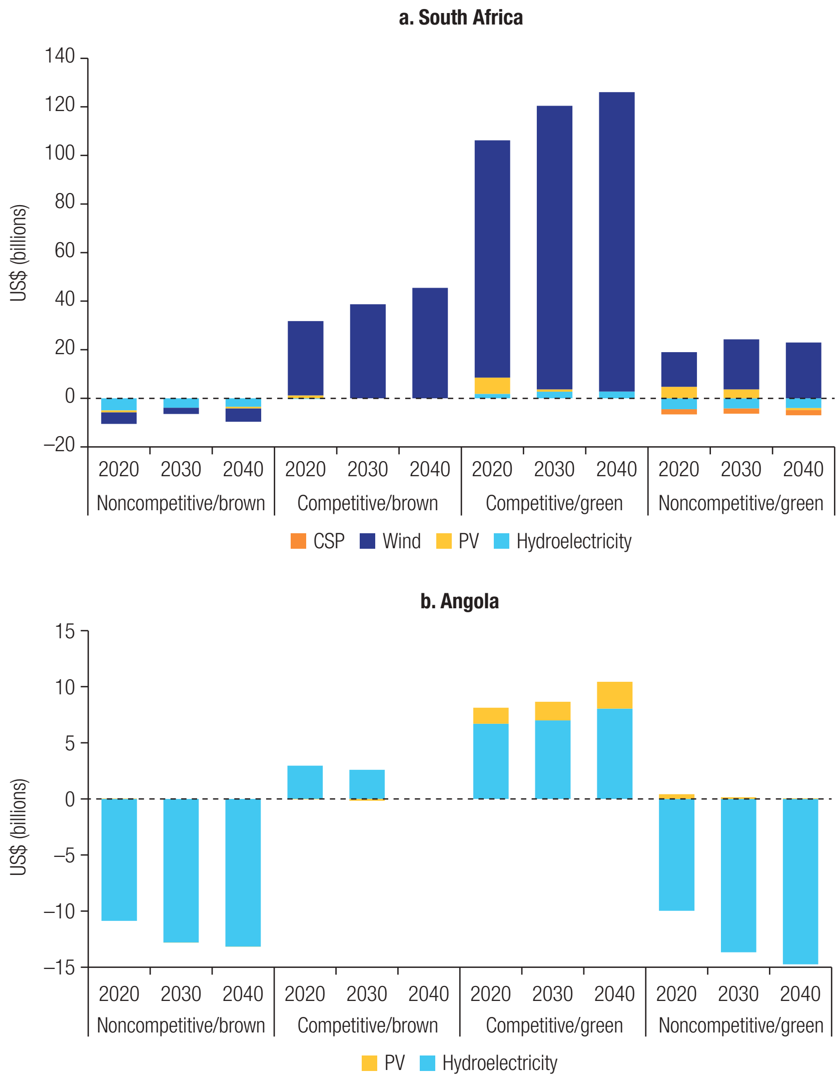
Four policy scenarios were simulated.

1. *The noncompetitive/brown scenario* is one in which all plants under construction are completed and operators of existing coal plants enjoy guaranteed operating hours and offtake electricity prices. No new carbon prices are applied, although the existing small effective carbon tax rate in South Africa is maintained. It is akin to the business-as-usual scenario, as in almost all developing countries coal power plants were built by state-owned companies or private developers under long-term power purchase agreements with different forms of guaranteed offtake and prices, leading to occasional curtailment of renewable energy producers.[18]
2. *The competitive/brown scenario* assumes electricity market reforms under which the system operator minimizes the system cost by not dispatching existing plants if they are not cost-competitive with more efficient power producers in meeting demand in any hour of the day, including with developers and operators of renewables. This implies that if the existing coal power plants cannot cover their capital and operational costs, they are retired prematurely from the power system (become stranded assets). No carbon price is introduced in this scenario.
3. *The noncompetitive/green scenario* assumes that thermal power plants remain protected from competition, but at the same time carbon pricing is introduced. China and South Africa are examples of countries that maintain this inconsistent incentive structure in the electricity system, just like even more countries that subsidize coal and renewable power plants at the same time.
4. *The competitive/green scenario* assumes the same competition-enhancing electricity market reforms and carbon pricing gradually introduced in 2025 and increasing linearly to US$100 per ton of carbon dioxide in 2040.

The simulations suggest synergy between electricity market reforms and carbon pricing. Both enhance wealth creation from renewable electricity by more than the sum of individual reforms applied separately (figure 14.11). If just one reform were to be implemented, however, a cost-competitive electricity market without carbon pricing would do more to the value of hydroelectricity than carbon pricing without market reforms. Wind wealth also benefits more from market reforms than carbon pricing alone. But carbon pricing seems to be necessary to evoke the market value of solar electricity assets in both countries.

In the noncompetitive/brown scenario, renewable energy sources do not generate wealth until after 2040 in either country, despite significant new solar and wind electricity production in South Africa by

FIGURE 14.11 Simulations of the Future Values of Renewable Energy Assets in South Africa and Angola, 2020–40



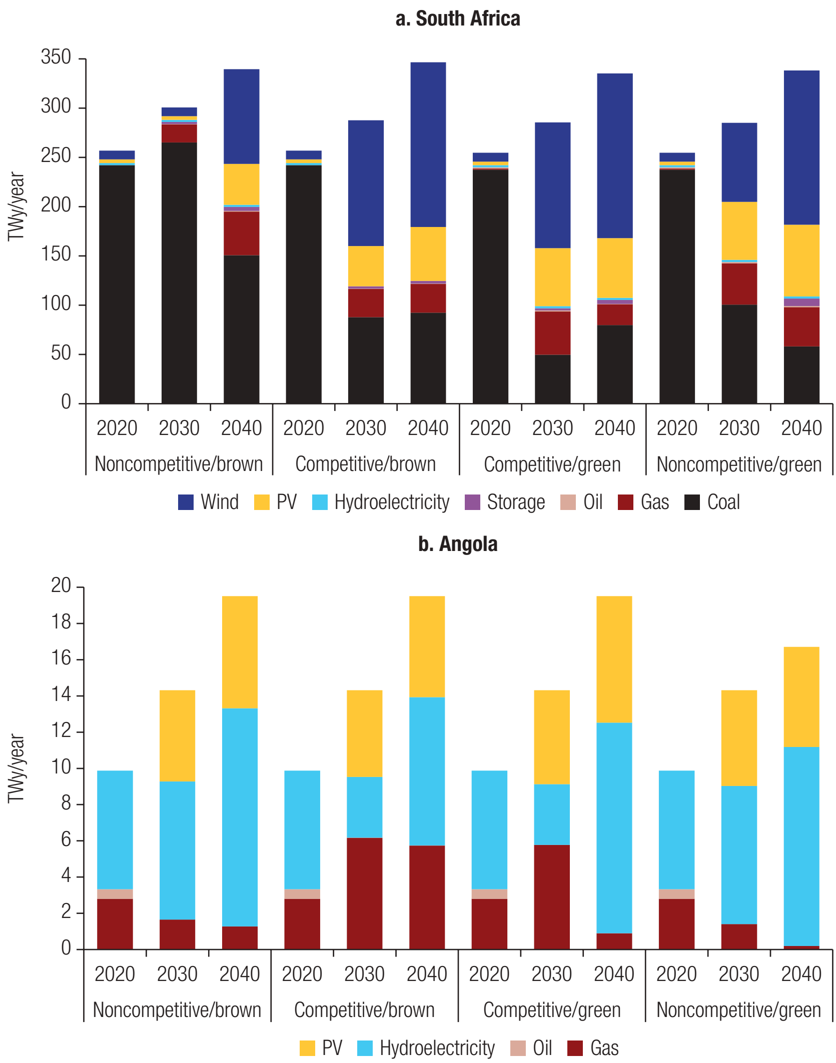
Source: World Bank staff calculations.

Note: Technically, an asset cannot have a negative value, but here negative numbers show "how far" renewable energy assets are from making positive contributions to national wealth. CSP = concentrated solar power; PV = photovoltaic. Noncompetitive/brown = retirement of existing plants not allowed, no carbon pricing; competitive/brown = retirement of existing plants allowed, no carbon pricing; competitive/green = retirement of existing plants allowed, carbon pricing; noncompetitive/green = retirement of existing plants not allowed, carbon pricing.

2040 and solar and hydropower production in Angola already in 2030 (figure 14.11). In this scenario, existing thermal plants (and those under construction in 2018) are assumed to be protected from premature retirement even if lower-cost renewable energy producers could be available. They are assumed to run at historical capacity factors and sell electricity until the end of their economic lifetime. Thermal power producers do not pay carbon prices for their greenhouse gas emissions.

The new capacity (renewable or not, depending on cost-competitiveness without carbon pricing) is built only to balance additional demand as it grows over time. Power plants retire after full depreciation. Existing solar, wind, and hydro producers are not producing when residual demand is zero, despite having lower short-term marginal cost than existing thermal plants. Reduced operating hours of renewable energy producers translate into lower revenues and inability to recover their capital cost. Changes in electricity generation mix (figure 14.12) show

FIGURE 14.12 Simulations of the Future Power Generation Mix in South Africa and Angola, 2020–40



Source: World Bank staff calculations.
Note: PV = photovoltaic; TWy = terawatt-year. Noncompetitive/brown = retirement of existing plants not allowed, no carbon pricing; competitive/brown = retirement of existing plants allowed, no carbon pricing; competitive/green = retirement of existing plants allowed, carbon pricing; noncompetitive/green = retirement of existing plants not allowed, carbon pricing.

that if South Africa protected existing coal power plants from early exit under competitive pressure, solar and wind energy without subsidies would not start displacing coal generation until after 2030 and would not create wealth even after they enter the market,[19] supplying only 5 percent of electricity in 2030 and 41 percent in 2040. Angola has a much smaller legacy of thermal plants (no coal) and experiences a much higher rate of growth of electricity demand than South Africa. Therefore, significant new solar PV generation is added already by 2030, as these are the most competitive new entrants (figure 14.12), but still do not generate wealth in this scenario.

The reason why renewables that enter the market do not create wealth in this scenario is explained by the nature of price setting in a competitive electricity market simulated by the model. In South Africa, continued operation of depreciated coal power plants—which no longer have capital costs but are inefficient and operate at low capacity for their category—depresses operating hours and market prices. They thus reduce revenues of the newly installed renewable energy generators, which in the model rely solely on revenues determined by the wholesale spot prices in specific operating hours. Without storage, solar energy also does not operate during the evening peak hours, when competitive wholesale prices are high. Absent other mechanisms to finance that gap (the model does not incorporate contractual or financial arrangements, subsidies, or guaranteed prices), the operators of new renewable power plants are not able to cover their capital cost from the market at all times, although they enter the market if their lifetime levelized cost of electricity is covered by the average market prices. Therefore, the asset value of renewable energy present in the system changes over time and can be negative even though power producers make lifetime profits.

The competitive/brown scenario makes a major difference to the market value of renewable energy, especially hydro and wind power. Reforming the electricity market by removing protection of thermal plants and providing economic dispatch of the most cost-effective producers on an hourly basis allows renewable power plant operators to increase their capacity utilization significantly and benefit from higher daily peak prices, even without carbon pricing and renewable subsidies.[20] It immediately flips the market value of hydro and wind assets to positive territory. In South Africa, the wind wealth increases to US$31 billion in 2020 due to higher spot prices, despite similar generation as in the noncompetitive/brown scenario. Wind and solar plants have very low operational costs because they do not entail costs for fuel and other materials. Operation and maintenance require fewer people than in other facilities. With just a few wind farms in the mix, the marginal producer (price setter) in the power system is usually an inefficient and expensive thermal plant, so wind farm operators receive a very high profit margin, which is close to resource rent on renewable energy with normal hurdle rates and without subsidies. However, as more renewable energy producers begin power generation, the most expensive thermal plants are crowded out of the merit order; hence, spot prices decline, reducing margins for renewable producers. If the renewable penetration gets very high during low-demand periods, spot prices may also reach zero for these hours as zero-marginal cost plants like solar and wind set the price. Renewable energy becomes a victim of its own success. Solar PV reaches 33 percent of generation in Angola and 14 percent in 2030 in South Africa, but unlike wind, its market value is close to zero in both countries for the entire period. Solar power plants produce the most electricity during the middle of the day, when demand and market prices are lower. Therefore, their revenue can barely cover their capital costs with return and pay for all the operational inputs. In contrast, wind energy in South Africa has a higher capacity utilization factor and, most important, wind patterns allow plant operators to produce during the morning and evening peak hours, when spot prices are highest. Therefore, wind power gains its share in the generation mix from 3 percent in 2020 to 44 percent in 2030 and 48 percent in 2040 (figure 14.12), proportional to the increase in its asset value. In Angola, competition in the electricity market favors locally produced natural gas, which—without carbon pricing—gradually squeezes out hydropower production, compared with the noncompetitive/brown scenario. However, the high marginal cost of gas turbines increases market prices; thus, despite lower production volumes, total hydropower wealth reaches US$3 billion in 2020. Wind has no generation and no value because Angola is not rich in wind resources.

Competitive electricity markets and carbon pricing work in synergy to enable large wealth creation by renewable electricity generation. Both policies create a level playing field between conventional and renewable power producers, due to fair competition and internalization of the social cost of carbon emissions.[21] These policy conditions enable immediate and significant wealth creation from renewable energy in both countries.

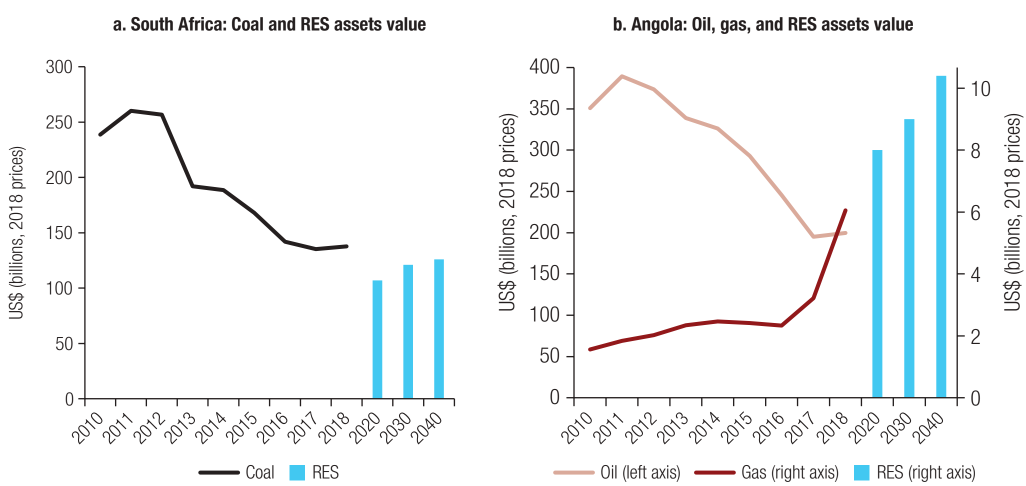
In South Africa renewable energy sources would create more than US$100 billion in wealth in 2020, increasing to US$130 billion by 2040, attributable almost entirely to wind power. For the reasons discussed, wind power in South Africa creates much larger wealth than solar power in absolute terms and per GWh generated.

In Angola, due to weak wind resources, allowing premature competitive retirement of thermal plants in the presence of carbon pricing boosts rents from hydroelectricity and solar power. The combined wealth created by both renewable sources reaches US$8 billion in 2020 and increases to over US$10 billion in 2040. In this scenario, until 2030, hydropower reduces average capacity factors under the competitive pressure of gas-fired electricity. After 2030, however, increased penetration of the low short-run costs of solar power forces early retirement of the most expensive gas turbines, creating more opportunities for longer operating hours and larger wealth from hydroelectric plants, reaching a total asset value of US$8 billion in 2040.

Applying carbon prices and protecting existing thermal plants is less conducive to wealth creation by renewable energy than electricity market reform without carbon pricing. Carbon prices initially create some value for solar energy assets in South Africa and Angola, but this value disappears around 2030 in both countries under the joint pressure of forced operation of thermal plants and competition from wind in South Africa and hydropower in Angola, both being able to produce electricity in peak hours when prices are highest. Wind power in South Africa can generate wealth, but it is much lower than in the other policy reform scenarios. In Angola, as existing thermal plants retire, hydro and solar power increase their shares in the electricity mix and produce almost 100 percent of power after 2030. The success in carbon-free power generation does not go together with wealth creation in the electricity sector. When thermal power plants disappear from the merit order, hydro and solar power plants, with near-zero short-term electricity production cost, become market price setters. As a result, the market prices and margins of renewable operators fall to very low levels. The simulations suggest that without electricity market reform, carbon pricing accelerates the decarbonization of the power sector, but this decarbonization may not be sustainable as it destroys the value of renewable energy assets. It may be difficult to attract large-scale investments in renewable energy if the sector does not create wealth.

The simulations suggest that with an enabling policy framework, the value of renewable electricity assets can match the value of fossil fuel assets in resource-rich developing countries. In South Africa, wind power wealth can quickly exceed declining coal wealth in the competitive scenario with carbon taxes (figure 14.13, panel a). In Angola, renewable electricity wealth is unlikely to match the value of oil reserves anytime soon, but it could have already been higher than national gas wealth with efficient policy reforms (figure 14.13, panel b).

FIGURE 14.13 Comparison of Fossil Fuel with Simulated Renewable Electricity Asset Values in South Africa and Angola



Sources: For fossil fuel asset values, CWON core accounts; RES asset values per World Bank simulations.
Note: The scaling of the vertical axes improves visibility but masks significant differences in the size of the two electricity markets. Angola has a 1,735 MW peak capacity in 2020, and South Africa reaches 38,356 MW. MW = megawatts; RES = renewable energy sources.

Discussion of Results and Future Research Agenda

Valuing renewable energy assets is complicated by the nascent state of renewable energy markets and technologies.

Hydroelectric assets have considerable value in every country studied. This provides empirical evidence confirming the theoretical notion that resource rent should rise in mature renewable electricity markets. There are several other studies of hydroelectric asset values against which the results here can be compared.

Gillen and Wen (2000) propose a method for estimating hydroelectric resource rent in the Canadian province of Ontario (which holds a substantial share of Canada's hydroelectric resources) using the cost of electricity imports as the least-cost alternative. Gillen and Wen's rent estimates suggest that Ontario's hydroelectric asset was worth about Can$33 billion in 1995[22] (US$37 billion in 2018 US dollars). The province's installed hydroelectric capacity grew by approximately 17 percent between 1995 and 2017,[23] suggesting a value of around US$43 billion for its hydroelectric asset in 2017. Ontario held 11 percent of Canada's installed hydroelectric generating capacity in 2017,[24] suggesting a rough estimate of US$378 billion for Canada's hydroelectricity asset in that year. This figure compares reasonably well with the estimate here of US$456 billion based on RVM.

In a study for the United Kingdom, the UK Office for National Statistics prepared an estimate of the value of the country's hydroelectricity asset using the RVM (ONS 2016). Data on revenues and costs were sourced from annual corporate reports and the asset was valued using a 3.0 to 3.5 percent discount rate[25] and an assumed lifetime of 50 years (which differs from the approach taken here of assuming infinite lifetimes for renewable energy assets). The estimated value of the United Kingdom's hydroelectric asset in 2014 was £9.2 billion (US$16.5 billion in 2018 US$), which is about double the estimate here of US$8.5 billion. Further investigation would be required to explain the discrepancy in the two estimates.

Solar and wind electricity assets were found to have negative market values in every country and year studied, with a few exceptions (onshore wind assets in the United Kingdom and Turkey) due to high production costs, especially in the early years of generation, and relatively high producer electricity prices. These findings are expected, given that both industries are nascent, although rapidly maturing, and the markets remain in a state of flux. Positive resource rents are not expected to rise under such conditions. Marshallian or quasi-rents may explain why there is some evidence of rents associated with onshore wind resources in a few countries, as early movers in the onshore wind electricity industry may have had opportunities to earn quasi-rents by capturing prime generating sites. The fact that rents arose in some countries for onshore wind electricity but not at all for solar electricity is explained by the higher private production costs of solar electricity on average than onshore wind electricity. Offshore wind rents, for their part, were negative everywhere, as would be expected given that offshore production began only relatively recently and involves high costs and risks.

Evidence supporting the findings for the value of wind energy is provided by the same UK study mentioned earlier (ONS 2016). Using an RVM approach in which subsidies were not accounted for (meaning the asset values were "social"[26] rather than market values), it finds that the value of UK wind electricity assets in 2014 was £45.3 billion, or US$81.6 billion in 2018 US dollars.[27] This compares reasonably well with the estimate here of US$55.3 billion for the United Kingdom's combined onshore and offshore wind electricity assets (excluding subsidies). As in the case of hydroelectric assets, further investigation would be required to determine why the estimate here is lower than the UK ONS estimate.

Further evidence supporting the findings for wind here come from a Statistics Netherlands (2011) study that estimates the value of the Dutch wind electricity asset using an RVM approach. Market and social asset values are estimated using a nominal discount rate of 6 percent. The authors find that the market value of the Dutch wind electricity asset is negative in every year from 1990 to 2010. Its social value, in contrast, is consistently positive after 2004. They estimate it to be worth more than 5 billion euros in 2010. Although this study does not consider the Netherlands, these results are largely consistent with the findings here for other European countries: little or no market value associated with wind electricity assets in any year, but positive asset values on the order of US$10 billion to US$100 billion (depending on the country) emerging consistently in the 2000s.

Although the results here are broadly borne out by those elsewhere, improvements could be made to the methodology that would provide greater confidence that no potential positive values for solar and wind electricity assets have been missed. These improvements relate mainly to the validity of RVM, treatment of subsidies, and depreciation and cost profiles and are discussed in the underlying technical paper (Smith et al. 2021).

Future values of renewable energy assets will depend on the policy framework under which they will operate. Wealth analysis helps distinguish policies that are successful in increasing clean energy generation from those that also create wealth to society and hence are sustainable in the longer term. Renewable energy subsidies have proven to reduce sharply the cost of clean energy generation and facilitate their scaling-up. As renewables such as onshore wind and solar PV are coming of age, however, going forward, power production subsidies can make renewable electricity profitable, but they do not create sustainable assets for nations (this argument holds for capex or price subsidies of power plants and not for upstream research and development subsidies). Competitive electricity markets with carbon pricing can make clean energy not only profitable but also wealth-creating without subsidies and even before counting local external environmental benefits. One of the main obstacles to sustainable value creation by renewable electricity is noneconomic dispatch of power plants in most developing countries, whereby power plants (including thermal) are built under long-term power purchase agreements that give them contractual rights (or political privilege in case of state-owned plants) to minimum operating hours and/or minimum offtake prices.

Such contracts create legacy thermal must-run plants and prevent market penetration and wealth creation from renewable energy, even if they are cheaper to build and operate. Such policy also increases the value of stranded thermal electricity assets should the country decide to accelerate green energy transformation and shifts the burden of paying for stranded assets onto the public sector.

Conclusion

This chapter argues that renewable energy represents an increasingly important, yet still unaccounted, wealth of nations. Its value already matches the value of fossil fuel energy in some countries (such as Brazil and Canada) and is likely to grow fast with the global low-carbon transition. Several lessons have been learned from this first experimental effort to develop renewable energy asset values for the CWON. First, and most important, the RVM approach used in the study produced results that cohere with theoretical expectations and that are largely borne out by comparison with the results of other studies. Hydroelectricity assets, as expected based on theory, were found to have mostly positive values, while the values for solar and wind electricity assets were mostly negative, again as expected.

Second, the estimated values for renewable energy assets are already large globally and likely to get larger in the greener and more flexible electricity markets of the future. The total estimated value of hydroelectricity assets in 2017 in the 15 countries studied here was about US$1.5 trillion. Although there was no value in these countries' solar and wind electricity assets in that year, this could have already changed when this volume went to press. These results show that leaving renewable energy assets off the national balance sheets is liable to miss a great deal of wealth in the not-too-distant future.

Third, there are sufficient data available from global and national sources to implement the RVM approach, although data on energy prices and the cost of the produced capital required to generate renewable electricity are not as robust as those on the quantities of electricity generated or the installed generating capacity. Finally, there remain several methodological issues to address before considering inclusion of renewable energy assets in the core CWON natural capital accounts.

Going forward, efficient energy and climate policy reforms can quickly turn the value of renewable electricity assets positive. Country-specific simulations with the power sector planning model suggest that by 2040 the value of solar and wind electricity assets in South Africa could reach US$126 billion (in 2018 US$), soon matching the value of coal assets. In Angola, national resources of hydro and solar energy can create more than US$10 billion of wealth with reforms simulated here. This would already be larger than the value of the nation's natural gas reserves. Cost-competitive wholesale electricity markets with carbon pricing, simulated here, can make clean energy profitable to project developers and can also create wealth to host countries.

Notes

1. Unless otherwise specified, all values in this chapter are expressed in US dollars measured in constant 2018 prices.
2. The SEEA-CF recognizes geothermal, hydro, solar, wave and tidal, and wind energy resources.
3. Other approaches are also possible. One that has been applied to the valuation of hydroelectric resources in Canada (Bernard, Bridges, and Scott 1982; Gillen and Wen 2000; Zuker and Jenkins 1984), Iceland (Hreinsson 2008a, 2008b), and Cameroon (Wandji and Bhattacharyya 2018) is the least-cost alternative method. In this method, resource rent is calculated as the difference in cost between using a given resource (say, hydroelectric resources) in a given production process (electricity generation) and using the next least expensive alternative (say, coal-fired thermal generation). The method is complex and data intensive. As Young and Loomis (2014, 213) note, "The analyst who undertakes to estimate the alternative cost of electricity generation 'from scratch' faces a major task." Another approach is the appropriation method, in which resource rents are assumed to be equal to the payments (for example, license fees and royalties) that governments demand from resource companies in return for the right to exploit resource assets. For a variety of reasons, the value of these payments does not usually reflect the full value of the underlying resource assets (see SEEA-CF paras. 5.126–5.130).
4. In the cases of solar and wind electricity production, results are presented from whatever year production began until 2017. Results for the Russian Federation are presented beginning in 1992 and include hydroelectricity assets only, as the country was part of the former Soviet Union prior to 1992 and it did not produce meaningful quantities of solar or wind electricity from 1992 to 2017. Results for Brazil are presented beginning in 1995, the first full year of circulation of the new Brazilian *real* that was introduced in mid-1994. Results for Turkey are presented beginning in 2005, the first full year of circulation of the new Turkish lira that was introduced at the end of 2004. Electricity prices denominated in the predemonetization currencies in Brazil and Turkey were unavailable, so results for those periods would not have been comparable with Brazilian or Turkish figures postdemonetization or with other countries predemonetization. Results for Germany in 1990 (prior to unification of the former East Germany and West Germany) were calculated based on 1990 data for the former West Germany and assumptions about the level of renewable energy production in the former East Germany in that year.
5. See International Renewable Energy Agency, Statistics Time Series database, Abu Dhabi, https://www.irena.org/Statistics/View-Data-by-Topic/Capacity-and-Generation/Statistics-Time-Series.
6. In principle, an asset cannot have a negative value (otherwise, it is a liability rather than an asset), so negative asset values should really be treated as zeroes. However, they are treated as negatives here to show "how far" renewable energy assets (especially solar and wind assets) are from making positive contributions to national wealth.
7. There is also an argument that the system costs of maintaining reliable electricity supply with a large share of variable renewable generation should be included in the cost formula. This cost, however, arises at much higher levels of solar and wind energy market penetration than observed in most countries

so far. Furthermore, if this externality of renewable energy were to be included, so should be the environmental cost of thermal generation. Both are considered as possible future developments of CWON.

8. Weights are the shares of the value of a country's asset in the total value of this asset in all sample countries.
9. The capacity factor measures the actual amount of electricity generated as a share of the potential amount that could be generated if a system operated at maximum output over a period. India's 1990 capacity factor of 0.436 had fallen to 0.303 by 2017. In Japan, the capacity factor fell from 0.293 to 0.206 over the same period.
10. A GWh is a unit of energy approximately equal to 590 barrels of oil. It is enough to meet the electricity needs of about 100 average Canadian homes for a year.
11. It was assumed that hydroelectricity was remunerated at the average annual electricity spot price. In reality, some hydroelectric producers likely received less than the spot price through long-term contracts. In such cases, hydroelectric prices may not have fallen as much over time as estimated here, although they would likely have been lower in the early years of the time period than estimated.
12. Turkish energy prices were rising when measured in lira but declining when measured in US dollars because of a decline in the value of the lira versus the US dollar.
13. Renewable energy asset wealth may be negative while exploitation of those assets to generate electricity remains profitable in the short run. In the long run, however, private profitability in the face of negative asset values can be maintained only if government subsidies are provided or private producers are willing to accept lower returns on their investments than they could expect elsewhere in the economy.
14. In 2017, Statistics Canada estimated that selected natural resource assets in Canada were worth the following: land, Can$4,208 billion; fossil fuels, Can$377 billion; timber, Can$236 billion; and minerals, Can$101 billion (or approximately US$3,237 billion, US$290 billion, US$182 billion, and US$78 billion, respectively). See Value of Selected Natural Resource Reserves (x 1,000,000), database, Statistics Canada, Ottawa, https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3810000601.
15. These projections are based on simple extrapolations of the data collected for 1990–2017 and rough assumptions on the evolution of renewable electricity technologies and markets. They are likely to have considerable margins of error.
16. CSP assets are not considered in this assessment because no country has long experience with this technology.
17. This study applies a least-cost long-run power sector expansion planning model for the South Africa Power Pool, which connects electricity markets in several countries in the southern tip of the continent. It was developed by the World Bank Power System Planning Group (Chattopadhyay et al. 2020). The model uses exogenous demand projections for each country in the pool and allows electricity trade and free entry of new generation plants choosing new capacity only on an economic basis, constrained by standard operational characteristics including transmission and cross-country interconnections capacity.

For this chapter, the model was not run in the typical constrained optimization mode but in a simulation mode with "what-if" policy scenarios representing uncertainty.

18. Most solar and wind projects also operate under such contracts, and power system operators sometimes have to make trade-offs.
19. South Africa does not have significant domestic hydropower resources.
20. Economic dispatch in a competitive electricity market, simulated in the model, is based on so-called merit order where the system operator calls power producers every hour to provide their capacity to the grid in the order of their short-run marginal (mainly operational) cost. The most expensive producer that meets the full demand in this hour sets the offtake electricity price, hence revenue, for all producing plants.
21. The scenarios simulated here demonstrate some residual bias in favor of variable renewable energy, since they do not include system costs of managing variability of wind and solar power, besides fast-response reserve margin.
22. Assuming a 4 percent discount rate.
23. Staff calculations based on Statistics Canada installed hydro generation capacity data.
24. Installed Plants, Annual Generating Capacity by Type of Electricity Generation, database, Statistics Canada, Ottawa, table 25-10-0022-01, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510002201.
25. A 3.5 percent discount rate was applied during the first 30 years in the net present value calculation and a 3.0 percent discount rate thereafter up to 50 years.
26. "Social" asset values are based on resource rents calculated without taking subsidies into consideration (Statistics Netherlands 2011).
27. As with hydroelectric assets, the UK study assumed a 50-year asset life for wind electricity assets (as opposed to the assumed infinite lifetime here) and discount rates of 3–3.5 percent.

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15

Social Capital and the Changing Wealth of Nations

Matthew Agarwala and Dimitri Zenghelis

Main Messages

- Social capital is not measured as part of the *Changing Wealth of Nations* (CWON) core accounts. Nonetheless, trust, networks, social interactions, and the ability to achieve outcomes requiring collective action are important determinants of social, health, and economic outcomes.
- Despite social capital's importance, the lack of a precise and universally accepted definition has undermined its measurement, valuation, and integration into mainstream economic analyses.
- Social capital is not readily amenable to valuation within the System of National Accounts, but this valuation challenge in no way reduces its impact on economic performance. Just as it did for natural capital, the evolution from theoretical concept to consistent accounting will take several decades of development and refinement.

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- Despite these challenges, progress in survey penetration and the use of higher-frequency data offer great potential for social capital research.
- Reflecting the importance of the concept, future editions of the CWON will include further examination of how social capital relates to, and interacts with, the core wealth accounts.

Introduction

Wealth is the best measure of prosperity. It captures a stream of benefits into the future, not just today's income. These future benefits include the consumption of goods and services, of course. But they also accrue directly or indirectly from living in a trusting, stable, and fair society. People are evidently willing to forgo current economic goods to secure the latter. Many of the social and institutional attributes resulting from this investment are long-lived, generating enduring returns that can be bequeathed to future generations. So it seems appropriate to consider these intangible social assets as part of wealth.

But what exactly is social capital and how important is it for prosperity? For individuals, social capital is a resource that encompasses personal relationships, civic engagements, and social networks whereby people access support and opportunities. For businesses, social capital relates to trust between firms, stakeholders, and investors and can significantly improve firm performance during times of crisis (Lins, Servaes, and Tamayo 2017). For the public, social capital is what enables societies to absorb and respond to shocks, including wars (Guriev and Melnikov 2016), climate change (Adger 2009; Semenza et al. 1996), the COVID-19 pandemic (Makridis and Wu 2021), and financial crises (Helliwell, Huang, and Wang 2014). It comprises shared norms and rules that enable cooperation and reduce the costliness of economic exchange by building trust. Some notions of social capital extend to incorporate physical infrastructure such as libraries and public parks—"Palaces for the People"—that facilitate social interaction and mixing among various demographic groups (Kelsey and Kenny 2021; Klinenberg 2018).

As a result, social capital is often referred to as the glue that holds societies together (Grootaert 1998). Without it, there can be little or no economic growth or human well-being. In business, social capital and trust enable companies to enter economic contracts or raise new capital. It lies behind the effective functioning of the police and judiciary, political stability, and democratic legitimacy as well as whether a government can raise tax revenues and provide public goods. In society at large, social capital is what enables communities of individuals to work together to achieve outcomes requiring collective action. Each of these functions is necessary for generating economic welfare.

On the other hand, social capital can also reinforce and perpetuate unproductive trends and relationships (Portes 2014). In the same way that a set of shared norms and rules of reciprocity can support a social order conducive to economic activity, they can alternatively be used to reinforce criminal codes of conduct. Indeed, gangs and mafia families possess some of the strongest measures of social capital. Even typically beneficial social networks can constrain behavior, reduce flexibility, and serve as a barrier to adopting new information and practices. For instance, Carrico, Truelove, and Williams (2019) show that higher community participation and perceived social cohesion among female and landless farmers in Sri Lanka resulted in worse outcomes following a drought (that is, higher loss of yields and income). Similarly, Wolf et al. (2010) describe how strong bonding networks can reinforce underestimations of the risks of heat waves to elderly populations in UK cities, ultimately increasing vulnerability to climate change. In contrast, Semenza et al. (1996) show that those who participated in church or social groups had a significantly lower risk of death during the 1995 Chicago heat wave. The conflicting findings indicate that the role of social capital in responding even to similar shocks may vary across cultural or demographic lines.

That trust, networks, social interactions, and the ability to overcome problems needing collective action are important to understanding social, health, and economic outcomes is perhaps uncontroversial. But despite its perceived importance, social capital has proven hard to define and measure precisely, not least because it encompasses so many diverse elements. Reviewing an expansive literature, Scrivens and Smith (2013) distill four broad interpretations of social capital: (1) personal relationships, (2) social network support, (3) civic engagement, and (4) trust and cooperative norms. While each dimension may require a separate measurement framework, most of these elements relate closely to generalized trust across a society and the functionality of key institutions. Because generalized trust enables social and economic cooperation, some argue that "social capital" may be best understood as a means to creating trust (Dasgupta 2011).

A key channel from social capital to economic outcomes is reduced transaction and monitoring costs, allowing the efficient allocation of resources in goods, labor, and capital markets (Dasgupta 2005, 2011). Society wastes resources when people distrust or are dishonest with each other. The economic literature on repeated games and punishment shows why cooperation makes social sense when people expect to interact in the future (Kreps et al. 1982). Yet people are surprisingly cooperative over and above what theory suggests is in their self-interest (Paldam 2000). This may reflect the fact that people gain direct utility from living in a trustworthy society; perhaps for evolutionary reasons, social connectedness brings most humans intrinsic pleasure. Indeed, research on the determinants of well-being routinely emphasizes the importance of social relationships (Agarwala et al. 2014; Helliwell 2006; Helliwell and Putnam 2004). This raises an important conceptual question: is social capital best thought of as an input into the economic production function, or as an argument in utility functions? A strong case can be made for both. Living in a supportive and trusting society is widely recognized to provide direct utility (Hamilton, Helliwell, and Woolcock 2016). But the full answer to this question determines the scope and strategy for measuring and valuing social capital.

In many ways, social capital exhibits wealth-like characteristics: it underpins future flows of benefits, people can invest in it, it can be degraded and depleted over time, and it contributes to production without necessarily being consumed in the process. However, there are conceptual challenges, too. As a latent construct, it has no standard unit of measurement, it is less straightforward to think of growth rates and stock dynamics for social capital than for other components of wealth, and it is particularly difficult to disentangle from human capital and other intangible assets. Nonetheless, social capital is clearly important to understanding changes in the capacity of individuals, firms, and nations to generate welfare into the future. As such, it deserves formal attention from economists.

Despite the myriad challenges in definition, measurement, and valuation of social capital, it remains an important component of the changing wealth of nations and deserves a dedicated research program. The field is not starting from scratch—there is already an important theoretical and growing empirical literature on social capital in economics (Arrow 2000; Dasgupta and Serageldin 2000; Glaeser, Laibson, and Sacerdote 2002; Knack and Keefer 1997; Putnam 2001; Scrivens and Smith 2013; Woolcock 2001). The purpose of this chapter is to flag key concepts and signpost important areas for further research. The goal is to demonstrate that social capital is a critical component of comprehensive wealth, that it matters to prosperity today and sustainability into the future, and that it may well be possible to develop credible, actionable measures of social capital for use in a range of economic and policy applications.

Overview of Conceptual Approaches to Social Capital

The question “what is capital?” has plagued economists for over a century. In his 1896 essay of that name, the US economist Irving Fisher noted that “of economic conceptions few are more fundamental and none more obscure than capital” (Fisher 1896, 509). Although he made many seminal contributions to capital theory, Fisher never found a satisfactory definition. Definitional challenges translate into measurement challenges, but this is familiar territory for those familiar with progress in measuring the changing wealth of nations (Lange, Wodon, and Carey 2018; World Bank 2006, 2011). Within the past century, the notion of natural capital has progressed from avant-garde metaphor to official statistical standard, with accounts compiled by more than 100 countries.

The System of National Accounts (SNA) (EC et al. 2009) and the European System of Accounts (ESA) (Eurostat 2013) have extensive guidelines on capital accounting. Beyond this, economists have continued to push the boundaries on what constitutes capital and how the changing wealth of nations might be measured. There is now a rich literature extending wealth accounts to incorporate human and natural capital

(Atkinson et al. 2014; Dasgupta 2014; Fenichel, Abbott, and Yun 2018; Hamilton and Hepburn 2017; Lange, Wodon, and Carey 2018; Managi and Kumar 2018; UNU-IHDP and UNEP 2012, 2014; World Bank 2006, 2011), and recent years have seen significant progress in developing international statistical standards for natural capital and ecosystem accounting (UN 2021; UN et al. 2014a, 2014b). A key lesson from this process is that it may take several decades, but it is possible to develop accounts to incorporate increasingly broader ideas about what constitutes wealth.

The term *wealth accounting* now casts a broad net, reflecting growing interest from governments, nongovernmental organizations, economists, and the general public in developing economic measures that go beyond gross domestic product (Atkinson et al. 2014; Coyle 2014; Dasgupta 2021; Hamilton and Hepburn 2017; Hoekstra 2019). Ultimately, how social capital is conceptualized and measured within a wealth accounting framework depends on many factors: how accounts are expected to be used, the availability and comparability of data, and agreements over the conceptual and measurement boundaries, such as those at the interface of social and human capital. While the growing prominence of wealth accounting is welcome, it is useful to distinguish between wealth accounts that are designed for use in sustainability analyses versus capital accounts designed to extend the SNA (EC et al. 2009; Eurostat 2013; OECD 2009).

Wealth accounts for sustainability analyses are based on the wealth theory of sustainability focused on assessing intertemporal welfare (Arrow et al. 2012; Dasgupta 2021; Dasgupta and Heal 1979; Weitzman 1976). Such accounts encompass a specific and specialized economic definition of *prices*, formally, "shadow prices," which reflect the marginal contribution of an infinitesimally small increase in the capital stock to the social welfare function (Arrow et al. 2012; Fenichel, Abbott, and Yun 2018). These shadow prices are conceptually and empirically different from the "exchange values"—the observed prices at which goods and services are formally traded in markets—reflected in the national accounts (EC et al. 2009). These conceptual differences can lead to substantial differences in measurement and especially in how assets and their services might be valued over time. As social capital and its services are not traded in markets, they leave no statistical "fingerprint" in the form of exchange values that can be readily included in the national accounts. However, this is also true of many components of natural capital and their subsequent ecosystem services, for which new accounting standards are being developed.

Definitions of Social Capital

The conceptual challenges around social capital begin well before issues of valuation arise. First is the issue of definition. As is often the case with capital, many competing and variously useful definitions exist. Nahapiet and Ghoshal (1998) identify three dimensions of social capital: (1) structural, which allows interaction among individuals; (2) relational, which produces interaction among the individuals as a result of long-lasting relationships (this incorporates trust and governance institutions); and (3) cognitive, which refers to elements of social organization (such as values or beliefs) that promote collective belonging and shared community vision. Forrest and Kearns (2001) decompose the concept further, identifying common values and a civic culture, social order and social control, social solidarity and reductions in wealth disparities, social networks, and place attachment as core components.

Putnam (2001) refers to social capital as the social networks that connect people (bridging) and the norms of reciprocity and trustworthiness that arise from them (bonding). Bourdieu (1986) and Lin (2002) also stress the network perspective. They describe social capital as a kind of resource nested in a social network. Woolcock (2001, 70) defines it more simply, as "the norms and networks that facilitate collective action." To support its social capital measurement work, the UK Office for National Statistics defines social capital as "the extent and nature of our connections with others and the collective attitudes and behaviors between people that support a well-functioning, close-knit society" (ONS 2020).

While a full review is beyond the scope of this chapter,[1] Scrivens and Smith (2013) distill four cross-cutting themes from their review of social capital, drawing on economics, sociology, and political science. They find four broad interpretations of social capital. In table 15.1, the rows distinguish between the individual and collective outcomes and activities, reflecting that social capital exhibits public and private good characteristics. The columns distinguish between the activities that create and maintain network structures versus the productive resources and outcomes those networks generate.

The relative importance of each component within the social capital matrix may change across cultures, income levels, and political and economic systems. For instance, the role and economic importance of family and personal relationships may reasonably be expected to differ across societies with well-functioning health or employment insurance markets versus those without. The matrix enables insights from various disciplines to be readily incorporated, recognizing that psychologists' interpretations of social capital tend to focus more on personal relationships, political scientists' tend to focus on civic engagement, and economists' tend to focus on trust and cooperative norms.

The distinction between the individual and collective elements of social capital is a recurring theme that poses challenges for definition and measurement. To fix ideas, Klinenberg (2018, 5) distinguishes between "social infrastructure: the physical places and organizations that shape the

TABLE 15.1 Social Capital Matrix

	Network structure and activities	Productive resources
Individual	Personal relationships	Social network support
Collective	Civic engagement	Trust and cooperative norms

Source: Scrivens and Smith 2013.

way people interact," such as libraries, parks, playgrounds, schools, and other public places where people interact. For Klinenberg, social infrastructure can be thought of as "the physical conditions that determine whether social capital develops." Kelsey and Kenny (2021) show that while "big infrastructure" projects often attract the most attention, small-scale locally managed social infrastructure is a key source of employment, particularly for young and marginalized workers in "left behind" places. Scrivens and Smith (2013) describe how networks of interpersonal relationships then generate social network support, while civic engagement breeds, and is further induced by, greater trust and broader cooperative norms. This reinforces the view that social capital is the combination of a collective component (the existence of social infrastructure, networks, and their benefits) and an individual component (a person's capacity or skill in accessing and utilizing that infrastructure and networks).[2] The connection to social skills or adeptness is one reason why disentangling social from human capital is so difficult, but defining these boundaries is crucial for wealth accounting, where the intertemporal welfare of assets is defined as an additive index of the value of each capital. If it is not possible to distinguish between the complementary effects of investing in human and social capital, the additive index could lead to double counting.

A key theme in social capital research entails distinguishing between "bonding" social capital, which refers to strong ties, relationships, and codes of behavior within a group, and "bridging" social capital, which refers to connections and interactions between groups (Gittell and Vidal 1998; Putnam 2001). The relative merits of bridging versus bonding social capital are open to debate. Gangs, corrupt elites, and criminal networks are a clear demonstration of how strong bonding social capital can be detrimental to society. Less obvious concerns are whether in the absence of sufficient bridging capita, strong bonding social capital can prevent the dissemination of new information or ways of doing things and ultimately stifle economic growth (for a brief discussion, see Agarwala et al. [2020]).

Is Social Capital Really Capital?

Given the range of definitions and interpretations, it is possible now to return to the question of whether social capital formally constitutes a capital stock and, if so, how economists should incorporate it into models, wealth accounts, official statistics, and policy advice. Ultimately, such questions may require an examination of the definition of capital that is beyond the scope of this chapter, but it is worth summarizing a few contributions from an economic perspective.

In many ways, social capital exhibits wealth-like characteristics (Robison, Schmid, and Siles 2002). It is investible, in that individuals devote time and effort to building social relationships. Businesses, charities, and universities dedicate scarce resources to networking events, and their attendees sacrifice leisure time to participate.[3] Such activities entail a current sacrifice of time and other resources to secure future flows of benefits and can therefore be considered capital investments. Social capital can grow and appreciate, if a person's network grows or includes more valuable members, or if the community provides new forms of support. But social capital can also depreciate, if trust is eroded, norms of behavior become obsolete or are no longer observed, or if community support wanes. Social capital is durable, in that it persists over time and is not consumed in the process of production (for example, sororities and fraternities at university provide access to networks throughout the career path). And finally, social capital is substitutable (if imperfectly), in that insurance markets can substitute for dependence on family to weather shocks.

Alternatively, social capital is a latent construct with no standard unit of measurement, making it difficult to think of an accumulated stock or its dynamics. Moreover, many of the descriptions and definitions of social capital refer more to the services that social capital might provide than to the stock itself. Indeed, Arrow (2000) and Solow (2000) caution against using the term *capital*, although they fully acknowledge the importance of trust, social norms, and relationships to economic performance (Robison, Schmid, and Siles 2002).

Dasgupta (2011, 119) argues that "the deep requirement for economic progress is the development of trust among people" and, defining it as "interpersonal networks," demonstrates that social capital is best considered as a "means to creating trust." Thus considered, Dasgupta proposes a notion of social capital that acts within total factor productivity (TFP), effectively scaling up or down what it is possible for a society to achieve with its other endowments.

Hamilton, Helliwell, and Woolcock (2016) focus on the role of social capital as a consumer "good," allowing social capital to directly enter the utility function as well as the production function. Conceptually, this is an important and unique contribution. Most of the economics literature has focused on the role of social capital in economic production. Hamilton, Helliwell, and Woolcock (2016) extend it to economic consumption, on the grounds that people may derive direct utility from living in a trusting society. There is strong intuitive appeal: a rich literature on human well-being confirms the importance of social relationships in human happiness and life satisfaction (Agarwala et al. 2014). Humans are, after all, social animals.

However, social capital remains challenging to reconcile with the SNA-consistent definition of asset. Assets as defined in the SNA are entities that must be owned by some unit, or units, and from which economic benefits are derived by their owner(s). The ownership need not be private but is nonetheless an important criterion for determining which entities can be considered assets, monetized, and included in the national balance sheets.

Measurement of Social Capital

Efforts to measure social capital reflect the broad range of conceptual interpretations and definitions just described. However, most of the empirical literature on social capital relies on responses to social surveys, sometimes in combination with other revealed data, such as blood donations or voting participation rates. Such measurement strategies have several advantages. They largely make use of existing data collection, reducing costs and ensuring the longest possible time series of data. The questions have typically undergone extensive testing and validation procedures, and most countries are generally covered by domestic or international surveys. However, because definitions and survey questions differ across countries, domestic social capital metrics may not align with data from international surveys, making comparisons difficult.

For instance, following the Organisation for Economic Co-operation and Development (OECD) framework for measuring social capital, the UK Office for National Statistics (ONS) measures social capital through a 25-indicator framework covering personal relationships, social network support, civic engagement, and trust and cooperative norms (see table 15.2). Such extensive surveys make it difficult to identify social capital trends without further statistical analyses—simultaneously assessing 25 survey responses is difficult. A common method is to conduct principal components analysis (PCA) to reduce the dimensionality of complex data and identify core concepts—or principal components.

PCA of the ONS social capital indicators identified five principal components with sufficient explanatory power for interpretation (ONS 2019). These emphasized (1) neighborhood relationships, (2) social engagement (for example, volunteering and membership in groups), (3) political engagement, (4) giving and receiving care, and (5) social relationships. Interestingly, although trust had high loadings across many of the components, it was not the highest loading on any individual component.[4]

In contrast, the state-level social capital index created by the Joint Economic Committee of the US Congress includes seven categories (subindices) of data, including (1) family unity, (2) family interaction, (3) social support, (4) community health, (5) institutional health, (6) collective efficacy, and (7) philanthropic health (see table 15.3). A more concise, four-subindex version was constructed for measuring social capital at the county level, providing a geographically rich index for use in further research.[5] Encouragingly, the 15 highest-ranked states on the social capital index are also the 15 highest-ranked states in Putnam's analysis (Putnam 2001). The US results indicate a clear North-South divide in social capital across the country, and clusters of states with high and low levels of social capital point to the possibility of "deep-seated roots in historical immigration and internal migration patterns, regional culture, and perhaps even features of climate and topography" in determining social capital in the United States (JEC 2018, 40).

The US and UK approaches to measuring social capital take advantage of existing social survey data. Thus, differences in the types of questions included may be an accident of the history of surveys in the two countries rather than any deliberate statement on what constitutes social capital. However, it appears that social capital metrics in the United States place greater emphasis on the immediate family (and especially how

TABLE 15.2 UK Office for National Statistics Social Capital Measurement

Personal relationships	
1.1	Proportion of people who have at least one close friend
1.2	Proportion of people who meet socially with friends, relatives, or work colleagues at least once a week
1.3	Feelings of loneliness often/always
1.4	Proportion of people who have used the internet for social networking in the last three months
1.5	Proportion of people who regularly stop and talk with people in the neighborhood
Social network support	
2.1	Percentage of people that have people who would be there for them if they needed help
2.2	Proportion of people who give special help to at least one sick, disabled, or elderly person living or not living with them
2.3	Proportion of parents who regularly receive or give practical or financial help from or to a child age 16 or over not living with them
2.4	Proportion of people who borrow things and exchange favors with their neighbors
Civic engagement	
3.1	Percentage who volunteered more than once in the last 12 months
3.2	Proportion of people who are members of organizations, whether political, voluntary, professional, or recreational
3.3	Proportion of people who have been involved in at least one social action project in their local area in the previous 12 months
3.4	Proportion of people who definitely agree or tend to agree that they can influence decisions affecting their local area
3.5	Voter turnout in UK general elections
3.6	Proportion of people who have been involved in at least one political action in the previous 12 months
3.7	Proportion of people who are very or quite interested in politics
Trust and cooperative norms	
4.1	Percentage of those who have trust in national government
4.2	Proportion of people who would say that most people can be trusted
4.3	Proportion of people who would say that most people in their neighborhood can be trusted
4.4	Proportion of people who definitely agree or tend to agree that their local area is a place where people from different backgrounds get on well together
4.5	Felt fairly/very safe walking alone after dark (men/women)
4.6	Proportion of people who agree or strongly agree that people around where they live are willing to help their neighbors
4.7	Percentage who agreed or agreed strongly that they felt they belonged to their neighborhood

Source: ONS 2020.
Note: Numbers show the category and number of the indicator per ONS.

TABLE 15.3 US State-Level Social Capital Index Indicators

Indicator
Family unity subindex
Share of births in past year to women who were unmarried
Share of women ages 35–44 who are currently married (and not separated)
Share of own children living in a single-parent family
Family interaction subindex
Share who report child spends at least four hours per weekday in front of a TV
Share who report child spends at least four hours per weekday on electronic device, excluding homework
Share who report someone in the family reads to child every day in past week
Social support subindex
Share saying they get the emotional support they need only sometimes, rarely, or never
Average number of close friends reported by adults
Share of adults reporting they and their neighbors do favors for each other at least one time per month
Share of adults reporting they can trust all or most of their neighbors
Community health subindex
Share of adults who report having volunteered for a group in the past year
Share who report having attended a public meeting regarding community affairs in past year
Share who report having worked with neighbors to fix or improve something in past year
Share of adults who served on a committee or as an officer of a group
Share who attended a meeting where political issues were discussed in past year
Share who took part in march/rally/protest/demonstration in past year
Membership organizations per 1,000
Registered nonreligious nonprofits plus religious congregations per 1,000
Institutional health subindex
Average (over 2012 and 2016) of votes in the presidential election per citizen age 18 and older
Mail-back response rates for 2010 census
Share of adults reporting some or great confidence in corporations to do what is right
Share of adults reporting some or great confidence in the media to do what is right
Share of adults reporting some or great confidence in public schools to do what is right
Collective efficacy
Violent crimes per 100,000
Philanthropic health
Share who report having made a donation of more than US$25 to a charitable group in past year

Source: JEC 2018.

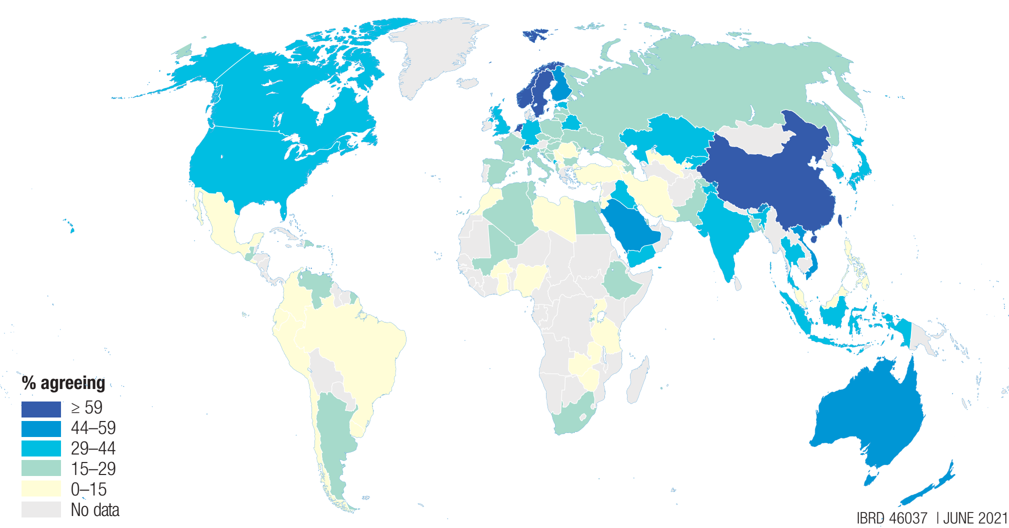
family members allocate time at home). This is an important consideration because the nature and relative weight of indicators comprising a social capital index can be expected to depend on cultural and social norms. For instance, in some places, the shared norm might be that individuals purchase health and employment insurance to cover themselves in case of emergency, whereas in others the norm might be that families and networks provide informal insurance.

The level of detail and coverage of social surveys varies considerably across countries, as might the most relevant components of social capital. For this reason, much of the social capital research relies on the trust questions found on international social surveys: for example, the World Values Survey (see map 15.1). These trust questions typically entail Likert scale responses indicating how much various groups from generic "others" to specifically "the police" can be trusted. The questions have a distinct advantage in that notions of trust are common and interpreted similarly across culture and language, and perhaps most important, they tend to have strong correlations with other more detailed components of social capital, such as those described in tables 15.2 and 15.3.

Map 15.1 demonstrates the coverage of trust questions in the World Values Survey and reports results for 2014. There is relatively good coverage across geographic, language, and development levels, although much of Sub-Saharan Africa remains underrepresented.

A common critique of all survey-based data is that respondents may provide strategic or otherwise inaccurate responses. For instance, it is not uncommon to find that people respond differently to the same question

MAP 15.1 Share of People Agreeing with the Statement "Most People Can Be Trusted," 2014



Sources: Our World in Data (database), Oxford, UK (accessed March 1, 2021), https://ourworldindata.org; World Values Survey 2014 (Inglehart et al. 2014).

depending on whether the survey is conducted face-to-face or online. To overcome these potential biases, some researchers have sought "revealed" measures of social capital, such as blood donations, voter turnout rates, or volunteering behavior. Conflict, crime, and violence also act as proxies for social capital (Chioda 2017). They are highly correlated with wealth accumulation with inequality often acting as a strong predictor.

Time Scales for Measuring Social Capital Trends

Accounts are tools for telling stories over time. For most of the components of comprehensive wealth, annual changes in stocks tend to be small relative to the level of the stock, indicating that annual accounts are sufficient. However, this may not be the case for social capital, especially if measurements are based on trust, which can change rapidly.

There are strategic complementarities associated with trusting others. An individual's perceived payoff to trusting others is a function of how others trust them. As social capital depends on expectations about others, this can make it unstable. A society can tip from cooperation to noncooperation merely on account of a change in expectations that pushes trust levels below a critical threshold. People who woke up in the morning as friends can yield machetes by afternoon. Consequently, the ability of social capital to secure future flows of benefits can collapse overnight. Thankfully, such rapid swings in social capital are rare.

Over time, norms of reciprocity and the complementarities associated with trust can build up a persistent stock of social capital. Like knowledge and physical capital, social capital also depends on history, making it highly path-dependent (Wildavsky 1987). Individuals' beliefs are influenced by values and social norms, which, in turn, are influenced by the products of society, such as institutions, trends, and technologies. This testifies to the fact that complementarities exist across assets.

Thus, there are two opposing interpretations. Is social capital an enduring stock built over long histories of reciprocity and mutual gain, or is it an unstable set of potentially rapidly changing norms and expectations? Algan and Cahuc (2014) refer to these interpretations as "Putnam I," following early views that social capital is a persistent stock (Putnam, Leonardi, and Nanetti 1994) and "Putnam II," after Putnam (2001) set out how social capital changes over time.

Unfortunately, most data on social capital, including on trust measures, come from surveys conducted annually at best. The European Social Survey, for instance, is conducted every two years. The paucity of high-frequency social capital data makes strong claims about the relative persistence or instability of social capital impossible. However, there is evidence to suggest that Putnam I and II are not necessarily mutually exclusive. Ananyev and Guriev (2019) exploit regional variations in the impact of the 2009 economic crisis in the Russian Federation to show that a 10 percent reduction in income was associated with a 5 percent reduction in trust and that trust did not recover to its precrisis level following the post-crisis recovery. Taking a different approach, Guriev and Melnikov (2016) construct weekly social capital data using internet searches for keywords related to prosocial behavior (for example, *blood donation*, *adopt a child*, and *orphanage*) during the violent conflict on the Russian-Ukraine border in 2014. Performing PCA on Google search data, they were able to construct a weekly social capital measure to estimate the effect of war on social capital. These studies demonstrate that high-frequency social capital data may reveal greater volatility in the stock than could be identified from lower-frequency surveys. The higher variation captured by these approaches could be useful for identifying causal relationships between social capital and other topics of interest.

Ongoing research at the World Bank and beyond has shown the high costs to society of social exclusion (Chioda 2017). Social exclusion not only erodes trust within society, often leading to social conflict, it also represents an economic loss in terms of forgone income, owing to untapped potential from low human capital accumulation, labor segregation, and discrimination. In Uruguay, for instance, it is estimated that if women enjoyed the same labor conditions as men, the collective gain would represent up to 14 percent of the national gross domestic product (World Bank 2020). The systemic failure of social institutions to allow individuals access to their full human capital amounts to a failure of state institutions with measurable consequences.

Valuation and Social Capital

A key contribution of comprehensive wealth accounting has been to value capital stocks and their associated flows of services in monetary terms so that they can be included in economic analyses. The greatest example is the economic valuation of ecosystem services and their core natural capital stocks (Bateman et al. 2014; Dasgupta 2021; Fenichel and Abbott 2014; Fenichel et al. 2016; Guerry et al. 2015; Pearce and Atkinson 1993; Pearce and Turner 1990). An important lesson from the economics of natural capital is the distinction between valuing capital stocks and valuing flows of environmental goods and services (Bateman and Mace 2020). This is because many ecosystem service valuation exercises effectively provide a point estimate of the marginal value of an additional unit of flow of the service. But those point estimates are unlikely to be constant across the full range of flows: for example, from scarce to abundant supply (Fenichel et al. 2016). If social capital is to be considered within the framework of wealth accounting, there is an opportunity and an obligation to learn from the methods and conceptual frameworks developed for valuing natural capital.

Although social capital is clearly important for the functioning of economic markets, it is not directly traded in them. As such, there is no clear market signal for the value of social capital. Economists have developed a range of tools and methods for valuing nonmarket goods and services (Champ, Boyle, and Brown 2003; Potschin et al. 2016). While social capital can be expected to present unique valuation challenges, core principles can be applied. Potential avenues to explore include valuing social capital via its impact on TFP, by examining data on search costs in labor markets; exploiting weak complementarities (Bockstael and McConnell 2007), for instance, with club memberships; measuring time and financial investments in networking activities; or employing hedonic valuation models, for instance of wage premiums attached to network size. Pursuing these avenues has the advantage of being consistent with economic theory.

Alternatively, research could focus on links between social capital and subjective well-being and attempt to derive compensating differentials—that is, to determine the change in income that would support equivalent levels of subjective well-being (Helliwell and Barrington-Leigh 2010). An important and unique contribution is by Hamilton, Helliwell, and Woolcock (2016), who develop an approach to use subjective well-being to compute wealth-equivalent values for social capital. Their approach requires first estimating the effects of changes in trust and income on subjective well-being, and then taking the ratio of those two effects to represent the income-equivalent value of any given level of social trust. This early attempt requires strong assumptions about the legitimacy of constructing income-equivalent values of subjective well-being, their comparability across countries, and the nature of the relationships between trust, income, and well-being. However, the approach utilizes available data and can be calculated consistently across a large range of countries; their sample consists of 132 countries, and they find that social trust is an important component of wealth in all regions, ranging from 12 percent of total wealth in Latin America to 28 percent in OECD countries.

Why Social Capital Matters for Economic Output and Welfare

The World Bank estimates that intangible capital may make up between 60 and 80 percent of total wealth in most developed countries (Lange, Wodon, and Carey 2018). Hamilton, Helliwell, and Woolcock (2016) suggest that much of this is social capital. Robust social capital based on trust, civic engagement, and effective institutions can support economic well-being and economic growth (Dasgupta 2011). Knack and Keefer (1997) find that a moderate increase in a survey-based measure of country-level trust significantly increases economic *growth* (a one-standard deviation increase in a survey-based measure of country-level trust increases economic *growth*, not just the level of activity, by more than one-half of a standard deviation).[6]

Workers in poor countries are three to five times less productive than those in the United States, taking into account the quality of machines and skill levels available for production (Hall and Jones 1999). Yet when these same workers migrate, they quickly earn salaries comparable to those of workers in their new countries. Something unrelated to the amount of physical and human capital available seems to be holding back productivity in poor countries.

Acemoglu and Robinson (2012) conclude that the main determinant of economic prosperity is functioning, inclusive, and law-based institutions. The centrality of institutions explains the infamous "resource curse": some countries with large endowments of primary commodities fail to benefit from subsequent economic growth when politically powerful groups enrich themselves through unabated rent-seeking and corruption (Sachs and Warner 1995). Corruption causes significant dissipation of resources. In rich countries, increasing focus is being paid to the role of institutions and generalized trust in explaining growing disaffection and populism among the "left behind."

Putnam, Leonardi, and Nanetti (1994) find a strong correlation between measures of civic engagement and government quality across regions in Italy dating back centuries. La Porta, Lopez-de-Silanes, and Shleifer (1997) find that across countries, a one-standard-deviation increase in the same measure of trust increases judicial efficiency by 0.7 of a standard deviation and reduces government corruption by 0.3 of a standard deviation. Goldin and Katz (1999) argue that social capital in the US Midwest brought on the rise of the public high school.

Coyle and Lu (2020) find that interpersonal trust, one of the essential components of social capital, has a significantly positive association not only with the level of TFP but, crucially, with its growth rate. This first-difference effect allows economies to generate additional resources for investment in a range of assets, including institutions that help maintain social capital. This exacerbates the presence of multiple equilibria and helps limit catch-up and convergence in incomes between poor and rich countries.

A University of Cambridge study applies PCA on 10 questions looking into different aspects of trust, a widespread metric for social capital from the European Social Survey (Zenghelis et al. 2020). The study finds clear patterns of trust in institutions and trust in individuals across different income and age groups. It finds that reported social capital tracked the slowdown of TFP growth since 2004, particularly following the 2008 financial crisis period, such that a 10 percent increase in trust is associated with an increase of around 1–6 percent in relative TFP levels.

Unsurprisingly, the causal mechanism between trust and economic growth is not fully understood (Algan and Cahuc 2010, 2014). It is likely that generalized trust and the quality of governance are a result of, as well as a cause of, productivity growth and higher reported well-being. But this feedback mechanism can be fruitfully exploited through sustained, carefully targeted policy interventions to trigger a virtuous cycle of good governance and higher productivity. It suggests that governments can and should invest in the quality of economic and political institutions, to enable broad-based social and economic participation.

Dasgupta (2011) presents a convincing theoretical model to demonstrate how interpersonal trust can *cause* higher output for the entire economy, with no change in the aggregate level of capital and labor inputs used. Empirical studies find that the quality of institutions and economic policies explains a significant part of the variation in growth rates across countries (Olson, Sarna, and Swamy 2000). Others find that the quality of governance and institutions is important for explaining rates of investment (Clague et al. 1999; Knack and Keefer 1995). Good institutions, checks on government that limit corruption, and environments that encourage social inclusion, creativity, and enterprise tend to attract investment and benefit from learning, experience, and innovation.

Olson, Sarna, and Swamy (2000) conclude that the quality of governance institutions accounts for a large part of the variation in the rates of growth and investment across countries. Clague et al. (1999) explain this using rates of investment. Investment in sound institutions includes providing assistance and financial support for local entrepreneurship in starting or expanding small and medium-size enterprises. This is related to employment opportunities and access to social services, especially for rural-urban migrants. It also involves issues of devolved government to ensure that local governments have strong and sustainable own-revenue sources.

The changes in governance and economic policy when Deng Xiaoping reformed Maoist mainland China, or the reforms in the Republic of Korea after Park Chung-hee replaced Syngman Rhee, offer historical examples. Even unsavory regimes have sometimes engendered economic stability for middle-class entrepreneurs. Cross-sectional evidence illustrates that institutions exert different economic influences on culturally similar societies: East and West Germany during the Cold War; the Democratic People's Republic of Korea and the Republic of Korea; mainland China compared with Hong Kong SAR, China, and Taiwan, China. In all these cases, institutional change preceded—and appeared to cause—changes in productivity. The issue of identification and causality is discussed further in subsequent sections.

The 2018 Nobel Prize winner Paul Romer argues that innovation that drives endogenous growth is not limited to technological capital and knowledge capital (Romer 2010); it also applies to rules, governance, and policies, which together drive TFP. Romer argues that social rules can hold back the potential introduction and exploitation of new technology. Indeed, new technologies are potentially harmful if they are not accompanied by rules that make growth sustainable—for example, rules that limit pollution, soil degradation, and overfishing; rules and ethical standards that regulate the use of artificial intelligence; or rules that limit economic rent-seeking from innovation via patents or market power.

The policy response to climate change, perhaps the most pressing social challenge of our time, and to coping with the challenges presented by new technologies such as artificial intelligence, big data, and automation requires institutions that enable the implementation of a range of policies that raise new risks and opportunities with corresponding distributional consequences in terms of generating winners and losers (Haldane 2018). Any policies that are not built on strong foundations of trust and effective institutions will meet resistance and likely fail.

Social Capital in Europe

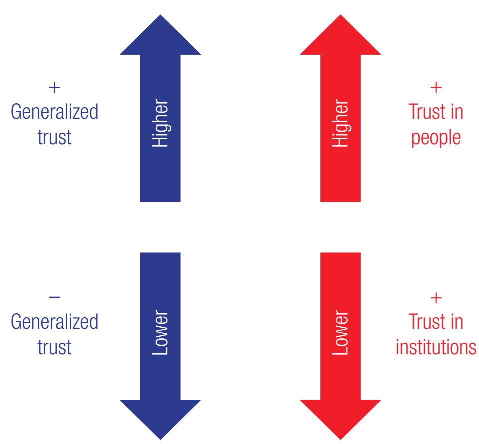
Exploring the measurement of social capital in Europe, research undertaken by the Bennett Institute for Public Policy at the University of Cambridge analyzed 10 questions relating to various aspects of trust, a widespread metric for social capital from the European Social Survey[7] (Zenghelis et al. 2020). Seven of these questions investigated trust in institutions, and three investigated trust in individuals.

Two underlying dimensions of trust are identified that can explain up to 65 percent of the variation in the initial 10 questions (figure 15.1), using the PCA data-reduction technique. The first dimension, *generalized trust*, shows a positive correlation with all 10 initial questions. The second dimension, *people versus institutions*, shows a positive correlation with the three initial questions investigating trust in individuals, but a negative correlation with the seven questions investigating trust in institutions. Such an approach, which leverages the commonality among different forms of trust, can yield a novel perspective on the essential, underlying elements of trust.

For instance, dividing the sample into five age groups and looking at how generalized trust evolves over time for each group reveals that those ages 15 to 30 show consistently higher levels compared with the other age groups (figure 15.2, panel a). Moreover, the gap between the youngest and the rest has been increasing over time. Repeating the same exercise for five groups based on income level (where the first quintile represents the lowest income group) shows that higher-income groups display higher generalized trust (figure 15.2, panel b).[8]

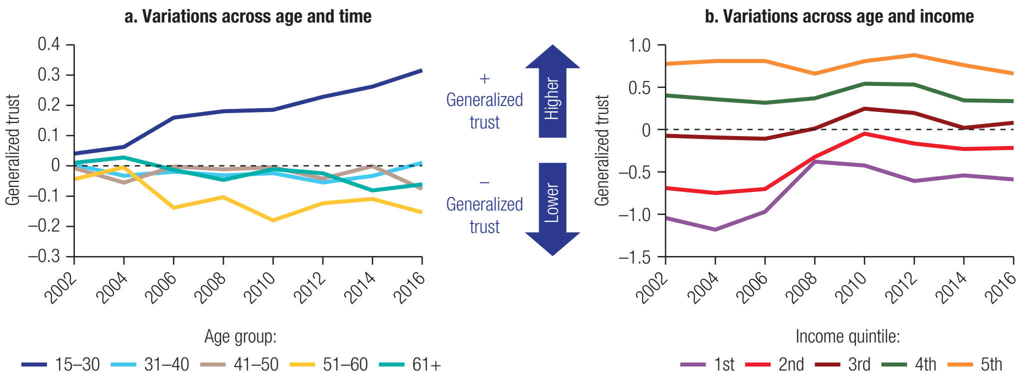
These correlations do not tell the whole story. Regression analysis can isolate a clearer relationship between age, income, and the two trust components, and it helps explain if other variables play a role in determining social capital. Figure 15.3 reports how age and income are related to the two components once the analysis accounts for a number of possible

FIGURE 15.1 Two-Component Structure of Trust



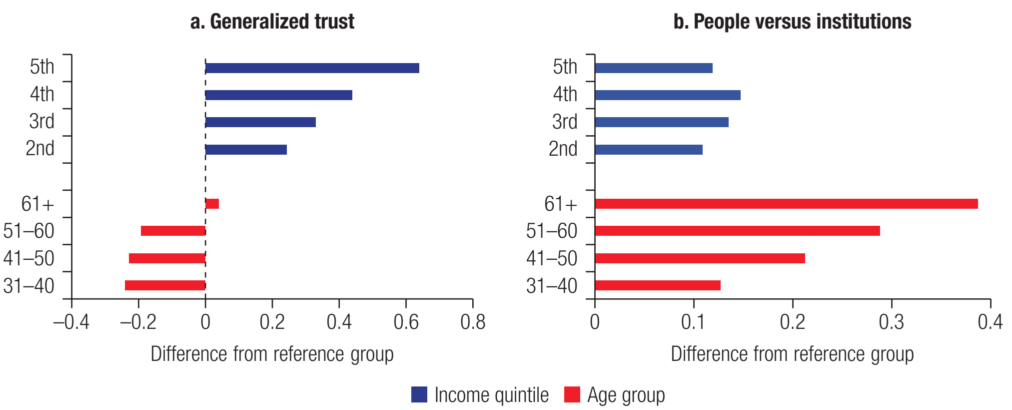
Source: Zenghelis et al. 2020. Used with permission; further permission required for reuse.

FIGURE 15.2 Generalized Trust: Variations across Age and Time, and Age and Income



Source: Adapted from Zenghelis et al. 2020. Used with permission; further permission required for reuse.

FIGURE 15.3 Regression Coefficients for Age and Income for Generalized Trust, and for People versus Institutions



Source: Adapted from Zenghelis et al. 2020. Used with permission; further permission required for reuse.
Note: For income (blue bars), the reference group is the first income quintile; for age (red bars), the reference group is the 15–30 age group.

confounding factors, including country of residence, date the survey was administered, demographic and socioeconomic variables such as gender and education, and additional measures of social capital.[9] The analysis also controls for inequality in the country using the Gini coefficient and for a measure of policy uncertainty at the country level.

Each bar in figure 15.3 represents the difference in the trust indicator between each group and the reference category, which is the first income quintile in the case of income (blue bars), and those ages 15 to 30 for age (red bars). The relative patterns observed in figure 15.2 still hold when the analysis controls for all the other variables. Indeed, all age groups show lower values for generalized trust compared with the age 15 to 30 group;[10]

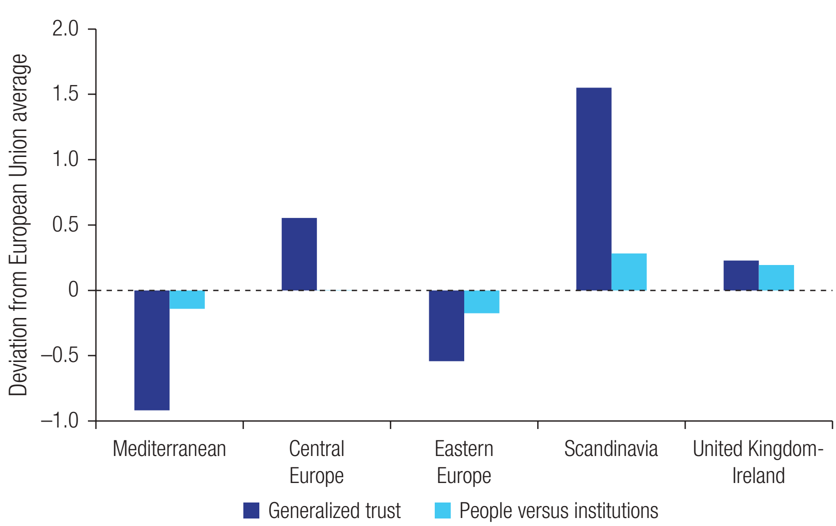
they also show higher values for people versus institutions (that is, they appear to trust individuals relatively more than institutions). By contrast, compared to the first income quintile, all other income groups show higher values for generalized trust (in agreement with figure 15.2) and people versus institutions. This finding suggests that young people are sizably more trusting than their older counterparts in general, but also relatively more trusting of institutions rather than people.

The two predicted underlying components can also be compared across locations. Figure 15.4 shows that deviations from the reference group differ across countries. The zero line can be interpreted as the European average, and the bars represent each subgroup's deviation from that average. Both components are highest for people in Scandinavia and lowest for those in the Mediterranean and Eastern European countries.

These results do not establish causality. It is impossible to claim, for instance, that higher income causes higher generalized trust, but it can be stated that the two are related. Identifying causal drivers is difficult given the complex relationships between the variables (figure 15.5).

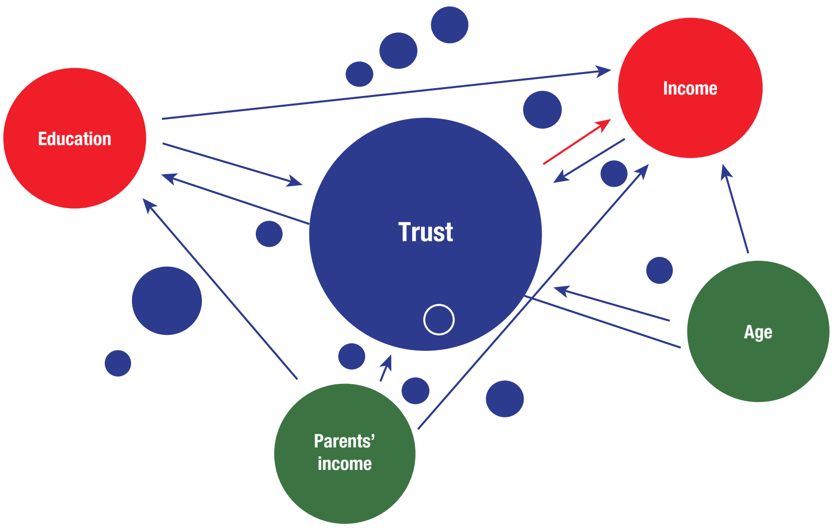
For example, variables such as age or parental income cannot be affected by other relevant variables and are therefore broadly exogenous. But income may be affected by parental income or education (which is itself affected by parental income), all of which may affect the level of trust, which may affect some of these variables in turn. Investigating this network of directed links to isolate evidence of causality forms the next aim of the research. It does not matter whether the egg came before the chicken in terms of mutual causality. What matters is that intervention can generate reinforcing feedback of greater trust, higher social capital, and higher productivity (see also box 15.1).

FIGURE 15.4 Trust within the European Union



Source: Zenghelis et al. 2020. Used with permission; further permission required for reuse.

FIGURE 15.5 Possible Causal Links between Exogenous Variables, Endogenous Variables, and Trust



Source: Zenghelis et al. 2020. Used with permission; further permission required for reuse.
Note: Exogenous variables are shown in green, endogenous variables in red.

BOX 15.1 Social Capital in China

The extent to which China manages to harness the strategic complementarities arising from investing in physical, human, natural, and social capital will determine the ability of the 14th Five-Year Plan to support stable and sustained growth for years to come (Hepburn et al. 2020; Stern, Xie, and Zenghelis 2020).

China recognizes the importance of social capital and a cohesive society. The government has sought to tackle inequality and recognizes the need for action to promote good governance (Shigong 2018). Managing disruptions and risks, for example, from new digital technologies; managing the low-carbon transition; and utilizing opportunities in innovation and investment require an emphasis on social harmony, opportunities for all, reducing inequality, and promoting social cohesion.

The Chinese authorities understand that environmental degradation has threatened health and social stability, while in many countries, sharply increasing shares of wealth and income for the rich have also threatened social cohesion and many have seen falling confidence and trust in social and political institutions.

A fruitful avenue for future work would be to apply principal components analyses using social surveys in China to "explain" the latent concept of social capital. The extent to which this is possible or helpful will depend on the quality of data already available or within scope for development.

Future Options for Linking Social Capital and Wealth Accounting

Reflecting the importance of the concept of social capital, future editions of the CWON will include further examination of how social capital relates to the wealth accounts. Further work will be necessary to define the conceptual role of social capital as a complementary enabling asset or a scaling factor applying to factor productivity. More thinking is required about indicators that act as linking pins between different capitals: for example, the measures of social competencies that form a reinforcing bridge between human and social capital. It would be valuable to examine the relationships that shape the realization of human capital's potential. For example, the New Zealand Ministry of Education is currently investigating the social support factors, including teachers, parents, peers, and institutions, that diverse students interact with and which enable them to thrive. Measures include the reported cultural responsiveness of teachers, parents feeling welcome at school, and experiences of bullying. A similar process is needed for each combination of capitals within the wealth framework. Adopting a wealth economy approach entails systematically identifying and exploiting strategic complementarities between assets (Agarwala et al. 2020), raising the returns to all assets (public and private), and enabling productivity growth and human flourishing.

Creating opportunities for diverse people to meet and positively interact requires that governments no longer take social capital for granted. The objective is to integrate a concern for social capital across the entire spectrum of public decision-making and assessing the impacts of decisions on inequalities and social capital ex ante rather than relying solely on ex post evaluations (OECD, forthcoming). A good example is Canada's Gender-based Analysis Plus policy analysis tool (Government of Canada 2020). Active investment enables successful collective action, for example in the face of COVID-19 as well as climate change (see box 15.2).

There is also a need to develop subnational measurement for all the key wealth components, including natural and social capital. The US county-level social capital index is an important example (JEC 2018). Regional variations in wealth are key determinants of inequalities of opportunity in terms of access to enabling assets. For example, areas with high crime or poor connectivity may exhibit relatively lower levels of social capital and community interaction, while areas of high pollution with limited access to nature might exhibit poor physical and mental health outcomes. COVID-19 exposed the degree to which such shortcomings in key assets increased exposure to the pandemic and limited people's ability to maintain welfare while socially distancing.

A powerful way to encourage governments in all countries to understand the importance of social capital is to demonstrate its economic impacts on productivity growth (Algan and Cahuc 2010; Coyle and Lu 2020), firm performance (Lins, Servaes, and Tamayo 2017), or in times of crisis (Makridis and Wu 2021), as well as impacts on education, health, and crime and the corresponding increase in the returns to all other public investments (Agarwala et al. 2020).

BOX 15.2 Social Capital and the COVID-19 Pandemic

Social capital affects disaster preparedness through multiple channels (pooling of resources, identifying unique needs, and protecting vulnerable populations) and at all stages (disaster planning, during the crisis, and recovery and future resilience) (Koh and Cadigan 2008; Wu 2021). Because it partially determines information sharing and the adoption of new social norms (for example, mask wearing, social distancing, other nonpharmaceutical interventions, and even perceptions of vaccines), social capital is an important asset for managing pandemics.

Research shows complex but important impacts of social capital on the early spread of COVID-19. Using voter turnout and blood donations per capita as proxies for social capital, Bartscher et al. (2020) analyze COVID-19 cases across seven European countries (Austria, Germany, Italy, the Netherlands, Sweden, Switzerland, and the United Kingdom) from mid-March to mid-May 2020. The results show that (1) the virus was initially more prevalent in areas of high social capital (consistent with higher initial levels of social interaction), but (2) as information about the virus improved, higher social capital was associated with better pandemic outcomes. For instance, high social capital areas accumulated between 12 and 32 percent fewer COVID-19 cases between mid-March and mid-May 2020. In Great Britain, Italy, the Netherlands, and Sweden, high social capital areas experienced between 7 and 14 percent fewer excess deaths compared to low social capital areas. A one standard deviation increase in social capital was associated with a 12 percent (Germany) and 32 percent (Italy) reduction in COVID-19 cases compared with low social capital areas (Bartscher et al. 2020). Similarly, studying more than 2,700 counties in the United States, Makridis and Wu (2021) find that moving a county from the 25th to the 75th percentile of the social capital distribution would reduce the cumulative number of infections and deaths by 18.0 and 5.7 percent, respectively. This demonstrates a clear empirical basis for the importance of social capital in managing the pandemic.

A potential channel through which social capital might affect pandemic outcomes is through its interaction with governance and the quality of institutions. Frey, Chen, and Presidente (2020) debunk the widely held myth that autocratic governments have been more effective in reducing the movement of people to curb COVID-19 transmission. Using a real-time data set tracking 111 countries, they find that while autocratic governments imposed more stringent lockdowns and relied more heavily on contact tracing, democratically accountable governments introduced fewer stringent lockdowns and were approximately 20 percent more effective in reducing geographic mobility at the same level of policy stringency. Frey, Chen, and Presidente (2020, 11) conclude that in terms of reducing mobility—a key strategy for limiting the spread of COVID-19—“collectivist and democratic countries have mounted relatively effective responses to COVID-19.”

The importance of social capital for public health is not limited to infectious diseases. Xue, Reed, and Menclova (2020) analyzed 470 published studies to demonstrate that social capital has a positive (if small) impact on the incidence of noncommunicable diseases such as cancer, heart disease, and diabetes.

Once the importance of social capital for economic growth, productivity, well-being, and resilience has been acknowledged, a crucial next step is to understand what activities and policies exist to generate social capital. Sawhill (2020) shows that increased interactions between people from different social, economic, political, ethnic, and educational backgrounds can generate social capital. Potential options include national service programs (for example, a conservation corps), increasing resources and decision-making power for local communities to direct investments, or providing an increased subsidy for charitable giving (thus encouraging prosocial behavior). Such programs could support the creation and maintenance of social infrastructure such as parks and green spaces (Kelsey and Kenny 2021; Klinenberg 2018). The OECD identifies improving public sector performance (in terms of responsiveness, reliability, integrity, openness, inclusiveness, and fairness) and strengthening public participation in decision-making as key pathways to building trust in government, and therefore, social capital (OECD 2017).

Ultimately, because social capital has value, people and firms have incentives to collaborate, transact, and connect ideas in a trusting society. This increases the potential for productivity growth based on utilizing all assets and characteristics of assets to generate creativity and innovation. However, the public good characteristics of social capital mean that it will be undersupplied by the market. Thus, there is a strong case for governments to act. Glaeser, Laibson, and Sacerdote (2002, 442) argue that "[i]n some communities, the level of investment is high and the return to investment is consequently high. . . . These complementarities raise the possibility that there exist multiple equilibria in the levels of social capital investment. . . . Multiple equilibria models explain how small differences in initial conditions can generate large divergence in long-run levels of social capital."

New editions of the CWON can fruitfully expand the data sets available for defining and measuring social capital. Many opinion surveys offer valuable information. These include the African, Arab, Asian, American, and Latino-barometers (which provide consistent metrics of trust in democracy, institutions, and markets), the World Values Survey, and country-specific household surveys. Other information sources, such as Mercy Corps surveys, can also inform future assessments of social capital.

Rapid transformative change needs to be managed carefully, whether it is from a crisis like COVID-19, decarbonization, artificial intelligence, automation, or digitalization. Reinforcing the social contract between the state and citizens and avoiding popular discontent and political polarization require that gains are seen to be equitably distributed and the losers supported. This requires enabling institutions to reskill, retool, and compensate affected workers (Haldane 2018); policies designed to compensate those who lose out;[11] and targeted place-based employment transition policies in areas at high risk of disruption (Austin, Glaeser, and Summers 2018).

Social capital is a crucial tool for navigating the economic challenges ahead: managing and recovering from the COVID-19 pandemic, reversing the trend in biodiversity loss, combatting climate change and managing the low-carbon transition, governing the digital economy, and addressing automation. Social capital is necessary for securing productivity growth, ensuring that climate change and environmental policies are deployed effectively and fairly, and enhancing resilience in the face of future shocks. The main barriers to recovery, structural change, and technological transformation are not economic or technological: they are institutional, behavioral, and political (Averchenkova, Stern, and Zenghelis 2014). Social capital is elemental and ubiquitous, so it is easy to overlook. Yet history shows that it is hard to overestimate the returns to measuring, monitoring, and investing in the social capital that is all around.

Notes

1. For a review, see Sobel (2002) or the more in-depth Dasgupta and Serageldin (2000).
2. The intersection of individual and collective components of social capital is demonstrated in Bourdieu's (1986, 248) definition: "Social capital is the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition—or in other words, to membership in a group—which provides each of its members with the backing of the collectively owned capital."
3. The wage premium attached to former politicians who join corporate boards or investment funds without any specific expertise in the field may be considered a signal of willingness to pay for social networks.
4. It is possible this may be because the question set included six questions with the word *neighbor* and only one question with the word *trust*. There is no penalty within this PCA for the number of similar questions.
5. The reduction in categories reflects data availability rather than a view that the components of social capital are different between these scales.
6. However, using data for the same countries for 1990–2000, Berggren, Elinder, and Jordahl (2008) found that the relationship between trust and economic growth was no longer as large or statistically significant.
7. Zenghelis et al. (2020) use the eight waves (2002–16) of the biannual European Social Survey, which comprises data at the individual level for more than 30 countries. (The sample varies depending on the year). The European Social Survey is a widely respected source and provides cross-country as well as cross-time comparability. It is also especially insightful on certain themes, including social capital.
8. A change in measurement for the income variable occurred between 2006 and 2008; therefore, the observed pattern of convergence in the series might be driven by it. In addition, generalized trust is de-meaned so that mean-shifting changes should not appear.
9. These measures include how often the individual meets socially, whether the respondent is a member of a trade union or a similar organization, how many people there are with whom the individual discusses personal matters, and whether the respondent voted in the previous national election.
10. With the exception of the 61- to 100-year-old group, for which the coefficient is statistically indistinguishable from 0.
11. Examples include proposals for the US Democratic Green New Deal to return carbon tax revenues to households, or former London mayor Ken Livingstone's popular use of congestion charge revenues to fund extra capacity on London's bus networks.

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Appendix A
Summary of Methodology and Data Sources

Introduction

This appendix summarizes the data and methods behind the comprehensive wealth accounts. The methodology builds on the foundation laid in previous works by the World Bank, including *Expanding the Measure of Wealth* (World Bank 1997), *Where Is the Wealth of Nations?* (World Bank 2006), and *The Changing Wealth of Nations* (World Bank 2011; Lange, Wodon, and Carey 2018). The innovation in this edition includes the addition of blue natural capital (mangroves and fisheries) and improvements on the measurements of other assets.

The following sections provide a brief overview of the methodology and data sources for estimating each wealth component. Detailed documentation of the data and methodology, and the technical studies and background papers that underlie the updated methodology, are available on the wealth accounting page of the World Bank website.

Data are reported in constant 2018 US dollars, at market exchange rates.

Total Wealth

A nation's wealth consists of a diverse portfolio of assets, which together form the productive base of the national economy. These assets include the following:

- *Renewable natural capital*, including forests (timber and ecosystem services), mangroves, fisheries, agricultural land (cropland and pastureland), and protected areas
- *Nonrenewable natural capital*, including fossil fuel energy (oil, natural gas, and coal) and 10 metals and minerals

- *Produced capital*, including machinery, structures, equipment, and urban land
- *Human capital*, including the knowledge, skills, and experience embodied in the workforce
- *Net foreign assets*, including portfolio equity, debt securities, foreign direct investment, and other financial capital held in other countries.

Total wealth is calculated by summing up each component of wealth:

Total wealth = renewable natural capital + nonrenewable natural capital + produced capital + human capital + net foreign assets.

A few methodological concepts and assumptions should be highlighted up front, as they are applied broadly to renewable and nonrenewable natural capital. The general concept of asset valuation is that the value should equal the discounted sum of net benefits an asset is expected to generate over its lifetime. For natural capital, the net benefits are the resource rents: the total value of production (or revenues) minus the total cost of production. In calculating the net present value for renewable and nonrenewable natural capital, a discount rate of 4 percent is used across all resources and years (as in the previous wealth reports).[1] The lifetime of the resource for renewable natural capital is capped to 100 years, following the practice of the UK Office for National Statistics, while the lifetime for nonrenewable natural capital is estimated directly based on reserves and extraction paths. Resource rents are smoothed as a lagged five-year average to avoid year-to-year price fluctuations. Resource rents for the core wealth accounts are assumed to remain constant in future years unless otherwise specified. This approach is supported by the System of Environmental-Economic Accounting (UN et al. 2014) in the absence of the ability to project future prices and extraction paths.

A country-specific gross domestic product (GDP) deflator is used for all natural capital components to bring the nominal values to constant 2018 US dollars at market exchange rates. The GDP deflator is a broad deflator that reduces price effects but may not eliminate all capital gains (or losses) that would be captured if a commodity-specific price deflator were to be applied.

Finally, the comprehensive wealth database generally draws on publicly available, global data sets. Although this approach has its limitations compared with country-specific assessments, it allows for consistency in cross-country analyses. Also, to maximize country coverage and gap-fill missing data, regional or income group averages are often applied. Countries that experienced economic and social crises, including population exodus during the period of study, typically have limited or unreliable macroeconomic and population data series, which require significant gap-filling. An example is República Bolivariana de Venezuela, where several key variables have an incomplete series. Missing values are filled by linearly extrapolating from past trends, an approach that may be sensible in countries with more stable macroeconomic and social environments, but less so in countries such as República Bolivariana de Venezuela.

Renewable Natural Capital

Forest Resources: Timber

The predominant economic use of forests has been as a source of timber. Timber resources are valued according to the present discounted value of rents from the production of timber over the expected lifetime of standing timber resources. Unlike fossil fuel energy and other nonrenewable resources, timber is a renewable resource, so the concept of sustainable use of forest resources is introduced when estimating how many years the current forest can generate timber rents. The lifetime of timber resources is determined by the rate of timber extraction (Q) relative to the rate of natural growth (N). If $Q > N$, then current rates of extraction are unsustainable and the lifetime of the resource is limited. If $Q \leq N$, then extraction is assumed to be sustainable and the lifetime of the resource is taken as 100 years. Starting with CWON 2021, the area of timber forest used in the calculation of annual natural growth is estimated by subtracting from the total forest area those forests located within protected areas, excluding protected area categories that could be used for sustainable timber production (that is, protected areas in International Union for Conservation of Nature categories five and six). The resulting timber forest area is broader than the more narrowly defined productive forest area used in CWON 2018 and previous data editions.

Rents from timber in a given year are calculated as the rental rate times total revenue, where total revenue is unit price times the quantity of timber extraction. Data sources for estimating timber wealth are described in table A.1.

Forest Resources: Ecosystem Services

Timber revenues are not the only contribution forests make. Nontimber forest benefits—ecosystem services—such as minor forest products, hunting, recreation, and watershed protection—are significant benefits not

TABLE A.1 Data Sources for Forest Timber Resources

Indicator	Data sources and notes
Production	• UN Food and Agriculture Organization (FAO), FAOSTAT database, http://www.fao.org/faostat/en/#home Timber production is the sum of coniferous industrial roundwood, nonconiferous industrial roundwood, and woodfuel.
Unit price	• FAOSTAT database Unit price is proxied by export unit value. Regional averages are then used to help correct the observed volatility in prices at the country level.
Rental rate	• Estimates by Applied Geosolutions 2015 A regional rental rate is applied to total revenues in the absence of country-specific production cost data. This rental rate additionally accounts for the price differential between export prices and domestic stumpage prices.
Life of resource	• FAO 2015, *Global Forest Resources Assessment* is used for data on total forest area and its breakdown, net annual increment, and growing stock of timber.

Source: World Bank.

TABLE A.2 Data Sources for Forest Nontimber Resources

Indicator	Data sources and notes
Total forest area	• FAO 2015, *Global Forest Resources Assessment*
Annual service values per hectare of forest	• Unit values are as estimated by Siikamäki et al. 2021 Annual values equal the sum of recreation, hunting, and fishing; nonwood forest products; and watershed protection.

Source: World Bank.

usually accounted for, which leads to the undervaluation of forest resources. This edition of *The Changing Wealth of Nations* builds upon the forest ecosystem services wealth introduced in the previous wealth report and presents results from the updated meta-analysis study that predicts annual, per hectare values for each service category per country based upon a spatially explicit metaregression model (Siikamäki et al. 2021). Compared to the previous report, this updated study broadens the coverage of forest ecosystem service values and employs machine-learning algorithms in its predictive models. Additionally, the study now provides a time series of ecosystem services values.

The annual value of forest ecosystem services is estimated by multiplying total forest area in a given year by the sum of the per hectare monetary values for the three benefit categories: nonwood forest products; recreation, hunting, and fishing; and watershed protection. The capitalized value of forest ecosystem services is equal to the present value of annual services, discounted over 100 years. No distinction is made between natural and planted forest. Monetary values are adjusted for inflation using country-specific GDP deflators. Also, values are estimated for the given year's forest area, assuming no change in forest cover in the future. See table A.2.

Mangroves

The asset value of mangroves is explicitly included in the World Bank's core wealth accounts for the first time in this wealth edition. As a type of forest, partial mangrove asset values are implicitly included in the forest asset accounts already. However, forest asset value is based only on value for timber, nontimber forest products, watershed services, and recreation services. Mangroves also provide a critical ecosystem service that is not currently included: protection from coastal flooding.[2]

The value of mangroves for coastal flood protection was estimated in several steps, which are further elaborated in Beck et al. (2021). First, a combined set of process-based storm and hydrodynamic models are applied

- to identify the area and depth of flooding,
- using model scenarios with and without reefs and mangroves,
- for five storm frequency events, 1 in 5, 10, 25, 50, and 100 years driven by local storm data.

TABLE A.3 Data Sources for Mangroves

Indicator	Data sources and notes
Total mangrove area	• Global Mangrove Watch database, www.globalmangrovewatch.org
Coastal assets at risk	• Coastal Population: Global Human Settlement Layer (GHS-POP GRID) data set, from the European Commission, https://ghsl.jrc.ec.europa.eu/ghs_pop2019.php • Coastal produced capital: Penn World Table version 9.1 produced capital data, spatialized using coastal population, https://www.rug.nl/ggdc/productivity/pwt/pwt-releases/pwt9.1?lang=en
Annual service values per hectare	• Modelled by Beck et al. 2021

Source: World Bank.

These flood extent and depth data are then overlaid on historical data on populations and the value of CWON produced capital assets, downscaled to 90 by 90 meters to identify a probabilistic distribution of flood damages (risk) and avoided damages (habitat benefits). All models were run for three years with data on the historical distribution of mangroves (1996, 2010, 2015), aggregated to the national level, then extrapolated and/or interpolated to provide annual values for 1995 to 2018.

Coastal flood risks and mangrove benefits were estimated for more than 75 nations covering approximately 700,000 kilometers of tropical and subtropical coastlines. Countries with fewer than 100 hectares of mangrove cover were dropped, and average values per hectare were capped at US$50,000 per hectare (to eliminate outliers). Table A.3 presents the data sources.

Fisheries

The asset value of marine fisheries is included in the World Bank's core wealth accounts for the first time in this wealth edition. Fisheries wealth is calculated as the discounted value of the stream of rents expected over the lifetime of the asset. Landed value is based on estimates of the Sea Around Us (SAU) project, which is more comprehensive and detailed than the United Nations Food and Agriculture Organization's (FAO's) fisheries data. SAU also has calculated fishing costs and subsidies, which are used to estimate financial and economic rent.

For the core wealth accounts, the lifetime of fisheries stock is set to 100 years, as with other renewable natural capital. Indicators of fish management status are estimated and will be incorporated in future work to reassess assumptions about the lifetime of fish stocks. The impact of two scenarios about climate change on fish abundance, spatial distribution, and maximum catch potential (MCP) are estimated using an integrated assessment model developed for the Intergovernmental Panel on Climate Change. The estimated MCP is linked to a bioeconomic model to assess the impact on landed value, rents, and asset value.

The calculation of fisheries wealth requires data on marine fisheries production (catch), ex-vessel price of each exploited species, and fishing costs.[3] The data sources for each indicator are included in table A.4.

TABLE A.4 Data Sources for Fisheries

Indicator	Data sources and notes
Catch	• Sea Around Us database, www.seaaroundus.org Data are collected on marine capture production (tonnes) of each country from 1991 to 2018 at species group level and spatialized.
Ex-vessel price and landed values	• Sea Around Us database, www.seaaroundus.org Ex-vessel prices are the prices that fishers receive directly for their catch, or the price at which the catch is sold when it first enters the supply chain.
Fishing costs and subsidies	• Fisheries Economic Research Unit (FERU) at the University of British Columbia (UBC) (Lam and Sumaila 2021), updated to cover years 1991 to 2018
Fisheries management status	• FERU at the UBC (Lam and Sumaila 2021), updated to cover years 1991 to 2018

Source: World Bank.

For the detailed methodology for calculating fisheries wealth, please refer to chapter 6 in this report, "Blue Natural Capital: Mangroves and Fisheries," and the supporting technical document by Lam and Sumaila (2021).

Agricultural Land

Agricultural land constitutes a considerable portion of total wealth in developing countries, particularly in the low-income group. For the purposes of the World Bank wealth accounts, agricultural land is conceptually divided into cropland and pastureland. There are potentially two alternative methods for estimating land wealth. The first method uses information from sales of land. The second method uses information on the annual flow of rents the land generates from crop and livestock production and takes the present value of such rents in the future. Given that information on land transactions is often missing, the second method is used. The value of cropland and pastureland is calculated as the present value of crop and pasture rents, discounted over 100 years.

For the first time, this wealth report accounts for the impact of soil degradation and climate change on future crop yield growth rates. Gerber et al. (2021) generated new country-specific crop-yield growth rates estimated at the grid-cell level, accounting for the impacts of future changes in precipitation, temperature, and degradation (driven by salinization, unsustainable irrigation, and erosion). This is an improvement over CWON 2018, which assumed fixed crop-production growth rates. Future crop production is based on projections of the yields of 10 major crops, which together comprise 83 percent of calories produced on cropland.

For livestock products, future rents are assumed to grow at a fixed annual rate of 1.475 percent for low- and middle-income countries and 0.445 percent for high-income countries.

The area of agricultural land is assumed to be constant: that is, wealth is estimated for the current area of land, not taking into account changes in the area of land that may affect rents in the future. See table A.5 for production and price data sources.

TABLE A.5 Data Sources for Cropland and Pastureland

Item	Indicator	Data sources and notes
Primary crop and livestock	Production	• UN Food and Agriculture Organization (FAO), Production, FAOSTAT database, http://www.fao.org/faostat/en/#home Crop products span the categories of cereals, fibers, fruits, nuts, oil crops, pulses, roots, spices, stimulants, sugar, and vegetables. Livestock products span the categories of meats, milks, and other (for example, hides).
Primary crop and livestock	Prices	• FAO, Value of Agricultural Production, Production, FAOSTAT database • FAO, Producer Prices—Annual Prices, FAOSTAT database Unit prices as reported in the FAO's estimates of the value of agricultural production are given priority, followed by the FAO estimates of producer prices. If country-specific data on prices are unavailable for a certain product, then regional or world averages are applied. Regional and world averages are weighted by production.

Source: World Bank.

Rental Rates

Cropland rents are estimated per crop product as production multiplied by the unit price multiplied by the rental rate. For crops, the rental rates are constant over time and crop products and are region-specific (Evenson and Fuglie 2010).

Pastureland rents are also estimated per livestock product as production multiplied by the unit price multiplied by the rental rate. However, rents from livestock products are different for livestock raised in extensive versus intensive production systems. Intensive systems are characterized by high output of animal products per unit surface area, and extensive systems use land areas of low production and under conditions of moderate grazing. For livestock raised in extensive production systems, the rental rate is assumed to be twice that for intensive systems.[4] The same regional rental rates assumed for crop products are assumed for livestock products in intensive systems. Therefore, when calculating pastureland rent, the rent is weighted according to the country's share of livestock production in extensive systems and intensive systems.

The share of livestock produced in extensive versus intensive systems is apportioned according to the percentage of ruminant meat produced in grazing systems, as estimated by the FAO for its Global Livestock Environmental Assessment Model.[5] The FAO estimates the percentage of meat produced in grazing systems for 228 countries and other administrative regions. Where country-level estimates of meat production in grazing systems by the FAO are not available, regional averages are applied (weighted by the total area of pastureland).

Protected Areas

Areas protected for conservation and preservation of ecosystems provide a range of services to the country. For instance, wildlife reserves can generate significant revenues for developing countries, in particular from international tourism activities. And about one-third of the world's big cities get their drinking water from sources in or downstream of protected areas, saving billions of dollars in supply and treatment costs thanks to forests and wetlands that regulate the flow of water and remove contaminants (Dudley et al. 2010). Valuing such ecosystem services on a global basis, however, is difficult. For this reason, protected areas are valued in the World Bank wealth accounts using a simplified approach. Under this approach, the quasi–opportunity cost of protection per unit area of land contained in terrestrial protected areas is estimated as the lower of cropland and pastureland's wealth per hectare. This value per hectare is then multiplied by the country's total terrestrial protected area, to arrive at the asset value of protected areas. This is likely to be a lower bound on the true value of protected areas.

Nonrenewable Natural Capital

Fossil Fuel Energy and Mineral Resources

Nonrenewable natural capital valued in the World Bank wealth accounts includes fossil fuel energy and mineral resources. The value of a nation's stock of a nonrenewable resource is measured as the present value of the stream of expected rents that may be extracted from the resource until it is exhausted. The present value of rents from fossil fuel energy and mineral resources is estimated under the restrictive assumption that rents remain constant in future years.

The fossil energy resources valued in the World Bank wealth accounts are petroleum, natural gas, and coal. Metals and minerals valued in the wealth accounts comprise bauxite, copper, gold, iron ore, lead, nickel, phosphate rock, silver, tin, and zinc.

Calculating the present value of future rents of nonrenewable natural capital requires data on annual production, prices, production costs, and proven reserves. From existing reserves and current rates of production, the time to exhaustion of the resource is assumed. Data sources for

TABLE A.6 Data Sources for Fossil Fuel Energy and Mineral Resources

Resource	Indicator	Data sources and notes
Oil and natural gas	Production	• Rystad Energy, UCube (upstream database), https://www.rystadenergy.com/energy-themes/oil--gas/upstream • International Energy Agency (IEA), "World Energy Statistics," IEA World Energy Statistics and Balances database, https://www.iea.org/data-and-statistics • IEA, "World Conversion Factors," IEA World Energy Statistics and Balances database • BP, Statistical Review of World Energy, https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html • US Energy Information Administration, International Energy Statistics, https://www.eia.gov/international/data/world#/? • UN Statistics Division, UN Monthly Bulletin of Statistics, https://unstats.un.org/unsd/mbs/app/DataSearchTable.aspx Production data from different sources are selected following a few decision rules, such as best coverage over time and median values among estimates.

(continued on next page)

TABLE A.6 Data Sources for Fossil Fuel Energy and Mineral Resources *(continued)*

Resource	Indicator	Data sources and notes
Oil and natural gas	Unit rent	• Rystad Energy, UCube (upstream database) Country data from Rystad Energy on unit revenues and costs for oil and natural gas are used to calculate average rental rates by region. Average rental rates are weighted by production.
Oil and natural gas	Proven reserves	• BP, Statistical Review of World Energy • US Energy Information Administration, International Energy Statistics
Coal	Production	• IEA, "World Energy Statistics" • US Energy Information Administration, International Energy Statistics • UN Statistics Division, UN Monthly Bulletin of Statistics Coal production is standardized on the basis of heat content and is broken down into two general categories: hard coal and brown coal.
Coal	Unit cost	• Wood Mackenzie, Global Economic Model database, https://www.woodmac.com/research/products/upstream/global-economic-model • Case studies from various sources • World Bank, Manufactures Unit Value Index, Global Economic Monitor Commodities database, https://databank.worldbank.org/source/global-economic-monitor-(gem)
Coal	Unit price	• World Bank, Global Economic Monitor Commodities database, • Government of Australia, Office of the Chief Economist, Department of Industry, Innovation and Science, Resources and Energy Quarterly database, https://www.industry.gov.au/data-and-publications/resources-and-energy-quarterly • IEA 1995, *Coal Information* Country-level estimates of unit production costs and prices are used to calculate average rental rates by region for thermal and metallurgical (coking) coal. Average rental rates are weighted by production.
Coal	Proven reserves	• US Energy Information Administration, International Energy Statistics • BGR (German Federal Institute for Geosciences and Natural Resources) 2015, *Reserves, Resources, and Availability of Energy Resources*
Metals and minerals	Production	• US Geological Survey (USGS), Minerals Yearbook and Mineral Commodity Summaries, https://www.usgs.gov/centers/nmic/minerals-yearbook-metals-and-minerals • British Geological Survey, World Mineral Statistics, https://www2.bgs.ac.uk/mineralsuk/statistics/worldStatistics.html
Metals and minerals	Unit cost	• S&P Global Market Intelligence for copper, gold, iron ore, lead, nickel, silver, and zinc, https://www.spglobal.com/marketintelligence/en • Country-specific case studies from various sources (assumed to be representative for the region) and cost index based on global average production costs from S&P for bauxite, phosphate rock, and tin.
Metals and minerals	Unit price	• World Bank, Global Economic Monitor Commodities database
Metals and minerals	Proven reserves	• USGS, Mineral Commodity Summaries and Minerals Yearbook, various years, https://www.usgs.gov/centers/nmic/mineral-commodity-summaries

Source: World Bank.

implementing and estimating each of these elements are listed in table A.6, and users should refer to the technical documentation for more detailed information.

Produced Capital

Produced capital consists of manufactured or built assets such as machinery, equipment, and physical structures. Estimates of produced capital stocks in the World Bank wealth accounts also include the value of built-up urban land, which is valued as a mark-up on other produced assets.

Several estimation procedures can be considered for the calculation of physical capital stocks. Some of them, such as the derivation of capital stocks from insurance values or accounting values or from direct surveys, entail enormous expenditures and face problems of limited availability and adequacy of data. Other estimation procedures, such as accumulation methods and, in particular, the perpetual inventory method, are cheaper and more easily implemented because they require only investment data and information on the assets' service lives and depreciation patterns. These methods derive capital series from the accumulation of investment series and are the most popular. The perpetual inventory method is, indeed, the method adopted by most Organisation for Economic Co-operation and Development (OECD) countries that estimate capital stocks (Böhm et al. 2002; Mas, Perez, and Uriel 2000; Ward 1976). This method is also used in the estimates of capital stock.

For most countries, estimates of physical capital are obtained directly from the Penn World Table (PWT) 9.1 database (Feenstra, Inklaar, and Timmer 2015). The PWT authors use the perpetual inventory method to estimate produced capital stocks for 182 countries between 1950 and 2017. For the World Bank wealth accounts, the PWT capital stock data are expressed in constant 2018 US dollars at market exchange rates, using the PWT's asset-specific investment deflators to bring the data to real terms. The value for 2018 (not included in PWT 9.1) is estimated using 2018 investment data from the World Bank's World Development Indicators and depreciation rates from PWT 9.1.

The physical capital estimates include the value of structures, machinery, and equipment, because the value of the stocks is derived (using the perpetual inventory method) from gross capital formation data that account for these elements. In the investment figures, however, only land improvements are captured. Thus, the final capital estimates do not entirely reflect the value of urban land.

Drawing on Kunte et al. (1998), urban land is valued as a fixed proportion of the value of physical capital. Ideally, this proportion would be country specific. In practice, detailed national balance sheet information with which to compute these ratios was not available. Thus, as in Kunte et al. (1998), a constant proportion equal to 24 percent is assumed; therefore the value of urban land is estimated as 24 percent of produced capital stock (machinery, equipment, and structures) in a given year.

TABLE A.7 Data Sources for Human Capital Calculations

Indicator/ variable	Data sources	Notes
Annual earnings	International Income Distribution database (I2D2)	Annual earnings are calculated utilizing the Mincerian regression results. The (relative) earnings profile by age, education, and gender are derived for each country and year given the corresponding data availability.
Education attainment	I2D2	Years of education by age and gender are derived for each country and year.
Employment rates	I2D2	The employment rate and self-employment rate by age, gender, and education level are calculated for each country and year. These rates have to be calculated by the employed (or self-employed) persons divided by the whole population that includes the employed, self-employed, unemployed, and the people out of the labor force.
School enrollment rates	I2D2	Whether an individual by age, gender, and education is enrolled in school or not; used for the probability of remaining employed in future years.
Employment	International Labour Organization (ILO), https://www.ilo.org/global/statistics-and-databases/lang--en/index.htm	The ILO employment data are used as control totals for scaling up employment from the I2D2 database. ILO employment data are also used for filling data gaps when necessary.
Compensation of employees, GDP	United Nations National Accounts database, https://unstats.un.org/unsd/snaama	The compensation-of-employees data are used as input to control totals for scaling up annual earnings estimates from the I2D2 database and for filling the data gaps. In addition, the GDP data are used for expressing variables as a percent of GDP.
Labor share of earnings of the self-employed	Penn World Table database, https://www.rug.nl/ggdc/productivity/pwt/?lang=en	Penn World Table estimates of the labor component of the earnings of the self-employed out of total earnings of the self-employed. Used as input to control total labor earnings.
Total labor earnings	United Nations National Accounts database and Penn World Table database	Compensation of employees plus labor earnings of the self-employed. This combined labor earnings estimate is used as control total for scaling up earnings estimates from I2D2 to national level.
Population	United Nations World Population Prospects, https://population.un.org/wpp	By sex and age groups: The distribution of workers from the I2D2 database is scaled up using the population data.
Survival rates	Global Burden of Disease Collaborative Network (GBD 2020)	Survival rates are calculated utilizing the death rates obtained from the GBD Study. The GBD database includes global, regional, and national age- and sex-specific mortality for 369 diseases and injuries in 204 countries and territories.

Source: World Bank.

Human Capital

The estimates of human capital follow the lifetime income approach developed by Jorgenson and Fraumeni (1989, 1992a, 1992b). According to this approach, human capital is estimated as the total present value of the expected future labor income that could be generated over the lifetime of women and men currently living in a country. Human capital is estimated by gender and type of employment (employed or self-employed).

The implementation of the lifetime income approach for estimating human capital requires data by age and gender on population, employment and labor force participation, education, earnings profiles, and survival rates.

The data sources for each variable are included in table A.7. For the detailed methodology of calculating human capital, please refer to chapter 7 in this report, "Human Capital: Global Trends and the Impact of the COVID-19 Pandemic," and supporting technical documents.

Net Foreign Assets

Net foreign assets (NFA) are a measure of the cross-border assets and liabilities held by a country's residents. A country's external asset position, or *NFA*, is calculated as

$$NFA = FA - FL, \tag{A1.1}$$

where *FA* are total foreign assets and *FL* are total foreign liabilities. Total foreign assets are

$$FA = equity_{\alpha} + FDI_{\alpha} + debt_{\alpha} + derivatives_{\alpha} + forex, \tag{A1.2}$$

where $equity_{\alpha}$ is portfolio equity assets, FDI_{α} is foreign direct investment assets, $debt_{\alpha}$ is debt assets, $derivatives_{\alpha}$ is financial derivatives assets, and *forex* is foreign exchange reserves (excluding gold). Similarly, total foreign liabilities are

$$FL = equity_{l} + FDI_{l} + debt_{l} + derivatives_{l}, \tag{A1.3}$$

where $equity_{l}$ is portfolio equity liabilities, FDI_{l} is foreign direct investment liabilities, $debt_{l}$ is debt liabilities, and $derivatives_{l}$ is derivatives liabilities.

The primary data source for *NFA* is the updated and extended version of the External Wealth of Nations Mark II database developed by Lane

TABLE A.8 Adjusted Net Saving's Components and Primary Data Sources

Component	Description	Primary data sources
Gross national savings (GNS)	Calculated as gross national income less total consumption, plus net transfers, a standard item in the System of National Accounts.	World Bank, World Development Indicators
Consumption of fixed capital (CFC)	Calculated as the replacement value of capital used up in the process of production, also a standard item in the System of National Accounts.	United Nations, OECD, and Penn World Table, with missing data estimated by World Bank staff
Current public expenditure on education (EDU)	Standard savings measures only count as an investment that portion of total expenditure on education (usually less than 10 percent) that goes toward fixed capital such as school buildings; the rest is considered consumption. Within the ANS framework, which considers human capital to be a valuable asset, expenditures on its formation cannot be labeled as simple consumption. As a lower-bound first approximation, the calculation thus includes current operating expenditures in education, including wages and salaries and excluding capital investments in buildings and equipment.	UNESCO: data extrapolated from the most recent year available

(continued on next page)

TABLE A.8 Adjusted Net Saving's Components and Primary Data Sources *(continued)*

Component	Description	Primary data sources
Net forest depletion (NFD)	Calculated as the product of unit resource rents and the excess of roundwood harvest over natural growth. If growth exceeds harvest, this figure is zero.	See "Forest Resources: Timber" section earlier in this appendix
Depletion of fossil energy resources (END)	Calculated as the ratio of the value of the stock of energy resources to the remaining reserve lifetime. It covers coal, crude oil, and natural gas.	See "Fossil Fuel Energy and Mineral Resources" section earlier in this appendix
Depletion of metals and minerals (MID)	Calculated as the ratio of the value of the stock of mineral resources to the remaining reserve lifetime. It covers bauxite, copper, gold, iron ore, lead, nickel, phosphate rock, silver, tin, and zinc.	See "Fossil Fuel Energy and Mineral Resources" section earlier in this appendix
Carbon dioxide damage (CO_2)	Cost of damage due to CO_2 emissions from fossil fuel use and the manufacture of cement, estimated to be US$40 per ton of CO_2 (the unit damage in 2017 US dollars for CO_2 emitted in 2020) times the number of tons of CO_2 emitted.	World Bank, World Development Indicators
Air pollution damage (POL)	Cost of damage due to exposure of a country's population to ambient concentrations of particulates measuring less than 2.5 microns in diameter ($PM_{2.5}$), indoor concentrations of $PM_{2.5}$ in households cooking with solid fuels, and ambient ozone pollution. Damages are calculated as foregone labor income due to premature death from pollution exposure.	Data on health impacts from pollution exposure from the Institute for Health Metrics and Evaluation's Global Burden of Disease Study
Adjusted net saving (ANS)	$ANS = GNS - CFC + EDU - NFD - END - MID - CO_2 - POL$	

Source: World Bank.
Note: OECD = Organisation for Economic Co-operation and Development; UNESCO = United Nations Educational, Scientific, and Cultural Organization.

and Milesi-Ferretti (2007). The Lane and Milesi-Ferretti database, last updated in early 2020, provides estimates of NFA for 1970–2019 for 214 economies. Where estimates of *NFA* and its components are not available in the Lane and Milesi-Ferretti database, additional data are obtained from various sources to extend the country coverage.

Adjusted Net Saving

Table A.8 provides a brief overview of the underlying components of the adjusted net saving (ANS) indicator and their primary data sources.

Notes

1. The 4 percent discount rate is the long-term (100 years or more) real return on financial assets globally, derived from Credit Suisse data.
2. Mangroves also provide protection from coastal erosion, but that value is not yet included.
3. *Ex-vessel* pertains to activities that occur when a commercial fishing boat lands or unloads a catch.

4. As recommended by Pierre Gerber, Senior Livestock Specialist, World Bank, April 2016.
5. See FAO, Global Livestock Environmental Assessment Model (GLEAM), Rome, FAO. http://www.fao.org/gleam/en/.

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Appendix B
Per Capita Wealth for 2018

The following tables show estimates of total wealth and its subcomponents by economy (table B.1) and by aggregate averages: income group (table B.2), geographic region (table B.3), and geographic region with only low- and middle-income countries included (table B.4).

TABLE B.1 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Economy, 2018

2018 US$

Economy	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests		Mangroves	Fisheries	Protected areas	Agricultural land		Nonrenewable natural capital	Net foreign assets	Population
					Timber	Ecosystem services				Crop	Pasture			
Albania	64,335	29,577	28,334	7,685	210	1,060	0	2	1,612	2,339	2,461	1,350	–2,611	2,866,376
Argentina	121,187	36,036	71,019	11,128	264	2,475	0	44	1,009	2,785	4,552	1,589	1,414	44,494,502
Armenia	48,031	17,263	28,775	4,888	229	438	0	0	849	1,793	1,579	287	–3,181	2,951,776
Australia	827,510	303,438	471,843	32,596	1,755	16,808	2,244	46	2,517	3,788	5,439	48,662	–29,027	24,982,688
Austria	633,748	269,968	351,301	11,578	802	6,034	0	0	971	1,117	2,655	362	538	8,840,521
Azerbaijan	36,315	11,475	8,367	3,157	19	377	0	0	353	1,335	1,072	16,121	–2,805	9,939,771
Bahrain	211,797	96,213	91,390	521	0	1	0	113	12	107	288	9,361	14,312	1,569,439
Bangladesh	19,265	5,346	12,934	1,167	7	12	64	22	14	907	142	56	–239	161,356,039
Belarus	77,516	30,775	40,798	8,987	1,243	1,913	0	0	736	2,219	2,876	517	–3,562	9,483,499
Belgium	571,179	230,343	318,355	4,260	208	1,342	0	25	226	1,210	1,249	0	18,221	11,427,054
Belize	38,206	12,856	19,777	11,533	477	4,250	1,066	685	1,323	3,343	389	569	–6,529	383,071
Benin	20,598	3,541	12,978	4,545	406	491	0	13	1,036	2,427	173	11	–478	11,485,048
Bolivia	41,592	7,321	25,146	7,939	361	2,818	0	0	1,453	1,867	1,441	1,806	–619	11,353,142
Bosnia and Herzegovina	46,718	17,909	26,044	4,605	750	1,520	0	0	48	1,567	720	772	–2,613	3,323,929
Botswana	80,602	28,552	41,391	7,544	683	3,356	0	0	1,305	177	2,023	511	2,604	2,254,126
Brazil	117,206	31,309	73,532	12,208	1,372	2,684	69	7	2,838	2,954	2,283	3,007	–2,850	209,469,333
Bulgaria	94,484	27,918	62,575	6,910	509	1,098	0	2	1,972	2,609	721	537	–3,455	7,025,037
Burkina Faso	8,487	1,942	4,307	2,331	675	331	0	0	264	673	388	241	–334	19,751,535
Burundi	4,594	515	3,517	739	88	33	0	0	37	494	87	6	–183	11,175,378

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TABLE B.1 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Economy, 2018 *(continued)*
2018 US$

Economy	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests: Timber	Forests: Ecosystem services	Mangroves	Fisheries	Protected areas	Agricultural land: Crop	Agricultural land: Pasture	Nonrenewable natural capital	Net foreign assets	Population
Cambodia	18,397	3,339	11,372	4,696	569	505	135	38	859	2,300	290	0	–1,011	16,249,798
Cameroon	23,656	4,392	13,699	5,621	1,191	731	13	21	1,239	1,931	497	349	–405	25,216,237
Canada	822,373	236,421	533,046	26,355	877	12,800	0	171	6,820	3,740	1,948	11,320	15,232	37,057,765
Central African Republic	8,958	2,428	951	5,910	1,268	830	0	0	887	1,155	1,771	1	–331	4,666,377
Chad	10,746	1,738	4,554	3,159	527	377	0	0	506	862	888	1,717	–423	15,477,751
Chile	191,983	54,329	120,469	9,650	2,156	2,015	0	145	862	3,587	885	11,288	–3,753	18,729,160
China	174,365	38,280	127,685	5,078	231	376	134	17	217	3,507	595	1,846	1,475	1,392,730,000
Colombia	83,065	23,119	55,814	4,784	231	1,172	29	2	486	1,648	1,215	2,128	–2,780	49,648,685
Comoros	18,698	7,276	9,932	1,567	213	117	78	243	95	603	219	0	–77	832,322
Congo, Dem. Rep.	9,017	1,152	4,342	3,366	1,893	608	0	0	99	708	57	394	–237	84,068,091
Congo, Rep.	44,125	18,050	16,184	7,093	2,178	2,542	0	45	619	1,265	445	7,577	–4,778	5,244,363
Costa Rica	158,035	30,255	120,291	13,918	2,847	2,173	65	13	1,875	4,510	2,434	2	–6,431	4,999,441
Côte d'Ivoire	19,324	4,073	11,028	4,436	987	527	6	22	151	2,468	275	277	–491	25,069,229
Croatia	148,289	66,021	81,958	7,904	907	2,794	0	26	2,198	1,415	565	803	–8,397	4,087,843
Czech Republic	275,897	130,119	144,851	5,456	895	1,414	0	0	873	1,264	1,010	744	–5,273	10,629,928
Denmark	842,148	304,464	487,962	9,192	282	3,625	0	193	480	2,194	2,417	2,664	37,866	5,793,636
Djibouti	18,933	5,859	13,276	1,985	7	13	54	2	18	149	1,742	0	–2,188	958,920
Dominican Republic	77,101	25,684	52,289	3,266	87	716	1	6	658	1,176	621	733	–4,871	10,627,165
Ecuador	107,013	28,710	68,249	6,596	510	747	77	35	2,055	1,952	1,220	4,217	–759	17,084,357
Egypt, Arab Rep.	18,271	3,501	12,958	1,945	2	2	0	7	487	779	669	1,575	–1,708	98,423,595

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TABLE B.1 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Economy, 2018 *(continued)*

2018 US$

Economy	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests: Timber	Forests: Ecosystem services	Mangroves	Fisheries	Protected areas	Agricultural land: Crop	Agricultural land: Pasture	Nonrenewable natural capital	Net foreign assets	Population
El Salvador	35,793	12,178	23,940	2,214	224	242	3	21	155	1,024	545	0	–2,538	6,420,744
Estonia	263,969	97,983	157,308	14,174	4,534	3,990	0	76	2,159	1,626	1,789	764	–6,261	1,321,977
Eswatini	47,505	8,537	30,873	7,290	2,997	1,046	0	0	79	2,065	1,102	88	717	1,136,191
Ethiopia	10,790	1,833	7,451	1,793	148	135	0	0	383	713	414	9	–295	109,224,559
Finland	614,630	250,745	342,068	24,300	4,025	15,001	0	25	1,958	960	2,331	753	–3,236	5,515,525
France	565,959	225,497	340,323	8,197	340	2,335	0	41	1,595	2,189	1,698	25	–8,084	66,965,912
Gabon	68,567	22,513	19,088	11,999	4,776	5,066	35	34	645	924	519	20,939	–5,972	2,119,275
Gambia, The	7,853	1,594	4,973	1,747	735	445	5	36	20	224	282	0	–462	2,280,102
Georgia	38,510	22,690	18,074	3,619	78	1,560	0	114	294	590	982	287	–6,159	3,726,549
Germany	672,408	258,165	381,761	5,292	375	1,848	0	7	583	1,161	1,319	232	26,958	82,905,782
Ghana	31,861	8,788	17,951	5,238	1,861	702	72	70	58	2,335	140	793	–910	29,767,108
Greece	194,266	122,332	89,600	10,695	57	2,659	0	51	2,311	4,197	1,420	308	–28,670	10,732,882
Guatemala	38,376	10,237	24,762	3,802	413	512	4	4	472	1,991	406	364	–789	16,346,950
Guinea	8,057	2,545	668	3,699	1,809	433	24	52	352	599	430	1,225	–80	12,414,318
Guyana	62,740	13,489	24,513	25,951	7,532	4,027	8,252	196	1,105	4,044	795	3,225	–4,438	779,004
Haiti	11,703	5,955	4,596	1,309	23	28	137	5	25	862	228	0	–157	11,123,176
Honduras	30,157	8,526	18,660	4,644	819	842	12	25	1,021	1,249	677	32	–1,706	9,587,522
Hungary	174,761	77,142	100,149	5,535	379	1,068	0	0	1,137	2,475	476	150	–8,215	9,775,564
Iceland	987,021	331,099	631,837	16,625	4	674	0	7,435	3,384	132	4,995	0	7,460	352,721

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TABLE B.1 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Economy, 2018 *(continued)*

2018 US$

Economy	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests: Timber	Forests: Ecosystem services	Mangroves	Fisheries	Protected areas	Agricultural land: Crop	Agricultural land: Pasture	Nonrenewable natural capital	Net foreign assets	Population
India	24,102	6,138	15,641	2,272	43	83	20	7	48	1,412	659	628	–576	1,352,617,328
Indonesia	48,046	17,038	26,493	4,025	415	198	112	92	358	2,671	178	1,685	–1,193	267,663,435
Iran, Islamic Rep.	84,546	26,359	25,314	4,349	14	200	8	7	526	2,513	1,080	26,172	2,352	81,800,269
Iraq	80,875	10,340	17,022	1,165	7	74	0	1	50	731	302	52,449	–100	38,433,600
Ireland	472,814	227,355	355,503	15,705	232	4,002	0	123	1,786	780	8,782	138	–125,886	4,867,316
Italy	375,541	179,857	192,539	6,118	91	1,366	0	33	1,432	2,380	816	274	–3,247	60,421,760
Jamaica	67,740	36,568	34,144	3,624	270	850	357	11	260	1,533	342	1,421	–8,016	2,934,855
Japan	559,259	229,869	302,453	2,755	155	808	52	69	310	814	545	37	24,144	126,529,100
Jordan	32,304	16,764	17,492	1,697	7	117	0	0	105	706	762	1,052	–4,702	9,956,011
Kazakhstan	109,074	32,785	47,630	4,704	9	396	0	0	117	1,732	2,450	28,073	–4,117	18,276,499
Kenya	22,055	3,566	15,260	3,617	808	91	10	6	464	833	1,406	1	–389	51,393,010
Korea, Rep.	356,619	141,631	204,085	2,964	107	624	0	78	81	1,488	585	32	7,907	51,606,633
Kuwait	748,480	93,438	108,247	1,298	2	2	0	9	276	372	637	343,148	202,349	4,137,312
Kyrgyz Republic	15,328	6,013	5,543	4,183	4	150	0	0	339	1,265	2,426	804	–1,216	6,322,800
Lao PDR	38,079	6,906	23,693	9,725	1,490	1,850	0	0	1,572	4,266	547	1,125	–3,371	7,061,507
Latvia	233,600	121,108	107,129	13,986	3,978	4,673	0	78	1,840	2,088	1,329	0	–8,623	1,927,174
Lebanon	51,673	26,481	33,966	2,323	3	255	0	2	26	1,635	402	0	–11,097	6,848,925
Lesotho	16,712	5,441	10,073	1,525	102	29	0	0	4	273	1,117	0	–327	2,108,132
Liberia	11,891	1,884	4,991	4,790	3,006	1,035	20	13	12	641	63	344	–120	4,818,977

(continued on next page)

TABLE B.1 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Economy, 2018 *(continued)*

2018 US$

Economy	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests: Timber	Forests: Ecosystem services	Mangroves	Fisheries	Protected areas	Agricultural land: Crop	Agricultural land: Pasture	Nonrenewable natural capital	Net foreign assets	Population
Lithuania	191,787	71,648	116,240	9,619	1,482	2,042	0	30	1,518	2,999	1,548	108	–5,827	2,801,543
Luxembourg	898,547	335,406	488,126	7,569	308	3,865	0	0	598	468	2,330	0	67,447	607,950
Madagascar	8,375	1,461	4,647	2,522	855	356	16	16	52	632	595	17	–271	26,262,368
Malawi	7,876	811	3,108	4,090	697	125	0	0	307	2,698	264	2	–136	18,143,315
Malaysia	167,365	32,314	118,362	10,198	4,826	795	57	92	1,231	3,141	56	7,134	–643	31,528,585
Maldives	50,795	24,074	37,819	230	2	2	0	104	0	121	0	0	–11,328	515,696
Mali	10,061	1,559	4,237	4,313	186	233	0	0	504	1,636	1,752	346	–394	19,077,690
Malta	296,649	77,028	200,180	1,398	0	2	0	334	73	692	298	0	18,043	484,630
Mauritania	18,501	6,060	9,285	3,768	69	75	67	381	48	196	2,933	1,739	–2,352	4,403,319
Mauritius	99,108	31,516	48,659	1,624	6	298	0	46	81	1,135	59	0	17,309	1,265,303
Mexico	98,664	43,754	52,432	4,762	313	1,328	142	24	424	1,312	1,220	2,442	–4,725	126,190,788
Moldova	31,608	22,601	6,719	3,833	253	588	0	0	146	2,226	621	8	–1,553	2,706,049
Mongolia	46,734	16,860	20,072	9,492	224	1,482	0	0	1,467	483	5,836	11,150	–10,840	3,170,208
Morocco	30,731	13,178	14,041	4,344	137	386	0	116	802	1,670	1,231	1,328	–2,160	36,029,138
Mozambique	6,505	1,354	3,551	2,700	1,046	447	15	15	57	972	147	689	–1,788	29,495,962
Namibia	66,120	13,086	45,920	7,028	1,010	2,169	0	186	1,428	496	1,739	999	–912	2,448,255
Nepal	15,280	4,464	6,719	4,044	191	148	0	0	942	1,763	1,000	1	52	28,087,871
Netherlands	690,432	232,889	412,939	4,664	61	1,009	0	60	80	1,506	1,947	2,792	37,149	17,231,624
Nicaragua	26,024	9,533	12,985	6,058	899	790	14	107	1,792	1,128	1,328	42	–2,594	6,465,513
Niger	7,507	2,194	2,876	2,688	26	92	0	0	625	1,112	833	163	–414	22,442,948

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TABLE B.1 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Economy, 2018 *(continued)*

2018 US$

Economy	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests: Timber	Forests: Ecosystem services	Mangroves	Fisheries	Protected areas	Agricultural land: Crop	Agricultural land: Pasture	Nonrenewable natural capital	Net foreign assets	Population
Nigeria	28,621	5,764	18,977	1,328	177	77	7	12	61	848	146	2,974	–421	195,874,740
North Macedonia	54,085	22,360	30,543	4,131	202	833	0	0	265	1,935	895	656	–3,605	2,082,958
Norway	1,185,533	412,587	534,177	32,883	855	22,722	0	1,352	4,306	600	3,048	54,370	151,516	5,311,916
Oman	165,669	49,869	74,519	2,618	0	0	99	222	534	842	920	48,053	–9,390	4,829,483
Pakistan	16,380	2,956	11,631	2,235	8	8	4	12	164	925	1,115	141	–583	212,215,030
Panama	129,946	60,017	79,902	5,777	371	2,274	58	81	929	1,152	912	37	–15,788	4,176,873
Papua New Guinea	33,011	5,832	15,264	9,649	1,689	3,024	114	80	591	2,656	1,496	3,045	–779	8,606,316
Paraguay	81,869	14,350	55,925	12,990	1,941	2,189	0	0	1,029	4,696	3,135	0	–1,395	6,956,071
Peru	79,464	22,875	48,000	5,850	284	1,548	1	186	1,141	1,897	795	5,418	–2,679	31,989,256
Philippines	35,135	8,468	24,559	2,380	182	134	4	60	441	1,410	148	238	–510	106,651,922
Poland	139,208	40,898	99,685	5,300	631	781	0	23	1,521	1,380	964	1,725	–8,400	37,974,750
Portugal	251,045	121,962	146,922	7,623	713	2,420	0	79	1,085	2,327	999	35	–25,498	10,283,822
Qatar	902,740	272,579	200,053	1,118	2	0	116	29	622	71	279	304,561	124,429	2,781,677
Romania	118,397	40,436	74,282	8,069	504	708	0	0	2,000	3,246	1,611	1,080	–5,470	19,472,545
Russian Federation	173,394	77,549	61,081	9,956	821	3,759	0	19	2,231	1,737	1,389	22,799	2,009	144,477,860
Rwanda	11,314	1,580	7,235	2,886	380	92	0	0	123	2,076	215	35	–422	12,301,939
Saudi Arabia	324,194	68,958	73,058	2,057	8	270	61	11	38	1,017	653	148,863	31,258	33,699,947
Senegal	15,217	4,530	8,878	2,454	734	498	53	203	209	519	239	147	–792	15,854,360
Sierra Leone	9,171	1,119	4,481	3,575	1,123	490	7	45	52	1,688	169	208	–212	7,650,154

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TABLE B.1 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Economy, 2018 *(continued)*
2018 US$

Economy	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests: Timber	Forests: Ecosystem services	Mangroves	Fisheries	Protected areas	Agricultural land: Crop	Agricultural land: Pasture	Nonrenewable natural capital	Net foreign assets	Population
Singapore	817,846	205,802	464,496	62	6	10	9	2	3	32	0	0	147,485	5,638,676
Slovak Republic	200,594	77,615	130,599	5,273	1,008	1,120	0	0	1,492	1,106	547	184	–13,077	5,446,771
Slovenia	331,087	126,532	198,899	10,351	1,323	2,761	0	0	3,834	849	1,583	155	–4,850	2,073,894
Solomon Islands	38,937	1,596	18,434	18,246	9,922	4,025	131	661	655	2,765	87	586	74	652,858
South Africa	64,366	20,165	36,610	3,700	961	422	4	8	125	1,094	1,086	3,221	669	57,779,622
Spain	328,253	145,900	198,351	7,730	188	2,121	0	83	1,180	3,385	774	156	–23,883	46,797,754
Sri Lanka	29,972	15,371	14,614	2,349	56	261	5	18	554	1,324	130	3	–2,365	21,670,000
Suriname	92,740	39,969	16,570	32,529	2,167	3,835	19,656	143	4,967	1,478	283	9,124	–5,453	575,991
Sweden	748,540	285,352	435,856	22,800	2,651	16,233	0	83	1,695	715	1,424	668	3,864	10,175,214
Switzerland	1,280,371	375,614	796,353	9,156	215	5,141	0	0	164	722	2,913	0	99,248	8,514,329
Tajikistan	24,668	18,889	4,433	1,773	9	66	0	0	389	818	491	241	–668	9,100,837
Tanzania	15,378	3,314	9,365	3,118	782	471	5	6	492	1,010	352	120	–539	56,318,348
Thailand	78,216	23,394	49,159	5,404	386	666	31	102	507	3,441	271	513	–255	69,428,524
Togo	13,612	2,726	8,997	1,700	137	49	0	3	265	1,070	176	329	–140	7,889,094
Trinidad and Tobago	117,979	22,485	81,658	2,698	233	692	64	42	1,111	507	50	12,288	–1,149	1,389,858
Tunisia	28,858	12,550	16,688	2,977	76	283	0	44	242	1,371	962	1,526	–4,882	11,565,204
Turkey	43,071	31,360	11,212	4,949	146	682	0	5	16	2,649	1,451	279	–4,729	82,319,724
Turkmenistan	102,707	33,795	40,473	5,806	0	1,432	0	0	180	464	3,729	22,822	–189	5,850,908
Uganda	10,407	1,823	7,598	1,387	62	60	0	0	222	676	367	6	–407	42,723,139

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TABLE B.1 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Economy, 2018 *(continued)*

2018 US$

Economy	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests: Timber	Forests: Ecosystem services	Mangroves	Fisheries	Protected areas	Agricultural land: Crop	Agricultural land: Pasture	Nonrenewable natural capital	Net foreign assets	Population
Ukraine	55,272	32,545	16,729	4,818	236	418	0	5	209	3,235	714	1,697	–517	44,622,518
United Arab Emirates	614,419	125,021	236,805	3,478	2	996	652	32	881	335	580	161,591	87,524	9,630,959
United Kingdom	493,795	167,719	326,843	3,607	58	820	0	28	770	682	1,250	1,060	–5,434	66,460,344
United States	872,400	263,930	621,460	12,977	579	6,092	78	49	994	3,084	2,102	4,304	–30,271	326,687,501
Uruguay	222,279	73,752	134,638	18,413	2,503	3,780	0	91	383	4,078	7,578	44	–4,568	3,449,299
Venezuela, RB[a]	226,787	26,689	172,133	6,975	180	3,280	107	11	2,045	569	782	17,414	3,576	28,870,195
Vietnam	34,084	5,512	22,870	5,829	982	308	1,233	153	90	2,840	224	1,348	–1,476	95,540,395
West Bank and Gaza	26,451	13,539	11,452	1,460	0	18	0	8	73	925	437	0	0	4,569,087
Yemen, Rep.	24,997	20,153	2,750	1,120	16	19	47	27	13	293	705	1,193	–220	28,498,687
Zambia	28,154	7,170	14,602	7,062	2,460	1,659	0	0	1,270	763	910	976	–1,656	17,351,822
Zimbabwe	23,319	4,129	15,641	4,071	1,077	1,328	0	0	569	436	662	393	–917	14,439,018

Source: World Bank staff calculations, http://www.worldbank.org/cwon/.

Note: Shaded columns represent large categories of renewable natural capital.

a. Economies that experienced economic and social upheaval during the period of study typically have limited or unreliable macroeconomic and population data series, which require significant gap-filling. An example is República Bolivariana de Venezuela, where key variables used to estimate wealth per capita (in particular human capital) such as gross domestic product (GDP) and GDP deflator have an incomplete series. Population has a complete series, but there is less certainty about recent trends properly reflecting demographic changes. Missing values are filled by linearly extrapolating from past trends, an approach that may provide a useful approximation in countries with more stable macroeconomic and social environments, but less so in countries such as República Bolivariana de Venezuela.

TABLE B.2 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Income Group, 2018

2018 US$

Income group	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests: Timber	Forests: Ecosystem services	Mangroves	Fisheries	Protected areas	Agricultural land: Crop	Agricultural land: Pasture	Nonrenewable natural capital	Net foreign assets	Population
Low-income	11,462	3,176	5,726	2,666	646	287	8	6	317	962	441	271	–377	594,477,664
Lower-middle-income	27,108	7,368	16,847	2,751	222	173	68	28	185	1,494	579	902	–761	2,859,498,919
Upper-middle-income	141,682	36,606	93,794	6,040	446	950	97	21	671	2,876	980	5,145	97	2,581,925,286
High-income: non-OECD	400,891	93,160	134,604	3,288	192	707	125	40	409	914	901	120,029	49,811	75,875,996
High-income: OECD	621,278	217,190	396,222	9,522	503	3,964	82	61	1,172	2,172	1,568	3,537	–5,192	1,080,750,510
World	**160,167**	**49,950**	**101,797**	**4,948**	**379**	**1,037**	**76**	**29**	**521**	**2,042**	**864**	**4,026**	**–554**	**7,192,528,375**

Source: World Bank staff calculations, http://www.worldbank.org/cwon/.

Note: Shaded columns represent large categories of renewable natural capital. OECD = Organisation for Economic Co-operation and Development.

TABLE B.3 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Region, 2018

2018 US$

Region	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests		Mangroves	Fisheries	Protected areas	Agricultural land		Nonrenewable natural capital	Net foreign assets	Population
					Timber	Ecosystem services				Crop	Pasture			
East Asia and Pacific	176,125	48,591	118,041	5,092	379	589	183	43	303	3,047	548	2,142	2,260	2,208,040,645
Europe and Central Asia	322,739	129,370	180,093	7,142	444	2,216	0	36	1,133	1,916	1,397	5,508	625	873,795,141
Latin America and the Caribbean	107,229	31,385	66,709	8,297	780	1,947	96	30	1,516	2,170	1,758	3,427	–2,588	624,044,951
Middle East and North Africa	102,927	25,680	30,989	2,623	22	157	30	24	379	1,232	779	36,097	7,537	374,216,883
North America	867,304	261,128	612,452	14,340	609	6,775	70	61	1,587	3,151	2,086	5,018	–25,635	363,745,266
South Asia	22,680	5,777	14,769	2,195	38	71	21	9	79	1,312	665	500	–562	1,776,461,964
Sub-Saharan Africa	20,473	4,619	12,278	2,906	740	367	8	15	290	1,021	465	1,084	–414	972,223,525

Source: World Bank staff calculations, http://www.worldbank.org/cwon/.

Note: Shaded columns represent large categories of renewable natural capital.

TABLE B.4 Per Capita Wealth and Its Subcomponents at Market Exchange Rates, by Region (Including Only Low- and Middle-Income Economies), 2018

2018 US$

Region (low- and middle-income economies only)	Total wealth	Produced capital	Human capital	Renewable natural capital	Forests		Mangroves	Fisheries	Protected areas	Agricultural land		Nonrenewable natural capital	Net foreign assets	Population
					Timber	Ecosystem services				Crop	Pasture			
East Asia and Pacific	137,269	31,089	98,751	4,966	384	373	171	41	282	3,228	488	1,754	710	1,999,283,548
Europe and Central Asia	103,772	48,116	38,540	7,021	459	1,861	0	10	1,107	2,158	1,426	11,337	–1,241	374,549,635
Latin America and the Caribbean	103,718	30,239	64,500	8,226	731	1,934	100	26	1,548	2,125	1,762	3,202	–2,450	596,299,761
Middle East and North Africa	46,645	14,218	16,555	2,700	25	126	7	22	399	1,316	805	13,945	–773	317,083,436
South Asia	22,680	5,777	14,769	2,195	38	71	21	9	79	1,312	665	500	–562	1,776,461,964
Sub-Saharan Africa	20,473	4,619	12,278	2,906	740	367	8	15	290	1,021	465	1,084	–414	972,223,525

Source: World Bank staff calculations, http://www.worldbank.org/cwon/.

Note: Shaded columns represent large categories of renewable natural capital.

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It is now clear that a narrow focus on the growth of gross domestic product (GDP) is insufficient to achieve humanity's aspirations for sustainable prosperity. Well-functioning ecosystems and educated populations are requisites for sustainable well-being. These and other too-often-neglected ingredients of national wealth must be addressed if the development path is to be sustainable.

The Changing Wealth of Nations 2021: Managing Assets for the Future provides the most comprehensive accounting of the wealth of nations, an in-depth analysis of the evolution of wealth, and pathways to build wealth for the future. This report—and the accompanying global database—firmly establishes comprehensive wealth as a measure of sustainability and a key component of country analytics. It expands the coverage of wealth accounts and improves our understanding of the quality of all assets, notably, natural capital.

Wealth—the stock of produced, natural, and human capital—is measured as the sum of assets that yield a stream of benefits over time. Changes in the wealth of nations matter because they reflect the change in countries' assets that underpin future income. Countries regularly track GDP as an indicator of their economic progress, but not wealth, and national wealth has a more direct and long-term impact on people's lives.

This report provides a new set of tools and analysis to help policy makers navigate risks and to guide collective action. Wealth accounts can be applied in macroeconomic analysis to areas of major policy concern such as climate change and natural resource management. This report can be used to look beyond GDP, to gauge nations' economic well-being, and to promote sustainable prosperity.

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