The CHANGING WEALTH of NATIONS

2024

Revisiting the Measurement of Comprehensive Wealth

WORLD BANK GROUP

This edition of *The Changing Wealth of Nations* is dedicated to the memory of Kirk Hamilton, whose pioneering work and intellectual leadership have made this work possible.

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Preface

Gross domestic product (GDP) is widely recognized as an insufficient measure of economic progress and national "success." Since GDP is nearly universally available and comparable across countries, it is extensively used as a benchmarking and reference statistic—even for purposes for which it was not designed. GDP measures the level of domestic productive activity, but it ignores the costs of this growth in terms of the environmental degradation that occurs in the process of production, for example. Sir Partha Dasgupta likened this to a soccer team that only measures success as goals for and ignores goals against.

Whether economic progress is sustainable can be measured by how real wealth per capita is changing, as this represents changes in future production (and ultimately consumption) opportunities. Wealth in this context encompasses the value of all the assets of a nation that support economic production, such as its factories and roads (produced capital); forests, fish stocks, and fossil fuel reserves (natural capital); labor force (human capital); and net foreign assets. As long as real wealth per capita does not decline, future generations will have at least the same opportunities as the current generation, suggesting that development may be sustainable.

All countries produce GDP estimates, but few measure wealth. The World Bank's The Changing Wealth of Nations (CWON) program addresses this gap. The CWON program is one of the pioneering efforts in measuring wealth, producing the most comprehensive, publicly accessible, and reproducible wealth database currently available. These monetary estimates draw on internationally endorsed concepts and valuation principles from the System of National Accounts and the System of Environmental-Economic Accounting. This ensures that CWON's wealth measure is methodologically rigorous and comparable to other metrics of economic progress like GDP.

Over the past two decades, the CWON program has updated and expanded its comprehensive wealth estimates with each new edition, as new data sources, measurement techniques, and guidance became available. This 5th edition continues this tradition and adopts international best practice in computing wealth in real terms. With this new approach, changes in real wealth per capita will be driven by (i) the depletion or accumulation of assets, (ii) changes in the productivity or relative scarcity of assets, (iii) changing substitution patterns, and (iv) increasing or decreasing competition for available assets—all of which are important for analyzing the sustainability of economic progress.

This report is intended primarily for a technical audience, including policy advisors, statisticians, and researchers. It first presents the rationale for using wealth as a measure of economic progress (chapter 1), explains in detail the CWON methodology (chapter 2), and presents global trends observed in the data (chapter 3). It then discusses how the methodology could be further improved to account for the increasing relative scarcity of key assets, most notably renewable natural capital (chapter 4). The subsequent chapters present the methodology and trends of the assets of the CWON wealth portfolio that are developed by the World Bank: nonrenewable natural capital (chapter 5), hydropower (chapter 6), forests and agricultural land (chapter 7), blue natural capital (chapter 8), and human capital (chapter 9). The final chapter concludes and outlines ways to use the CWON database.

ACRONYMS AND ABBREVIATIONS

CPI	Consumer price index
EEZ	Exclusive economic zone
EIA	US Energy Information Administration
ERRA	Energy Regulators Regional Association
EWN	External Wealth of Nations
FAO	Food and Agriculture Organization
FCV	Fragility, conflict, and violence
FERU	Fisheries Economics Research Unit
GDP	Gross domestic product
GEM	Global Economic Model
GHG	Greenhouse gas
GMW	Global Mangrove Watch
GNI	Gross national income
GWh	Gigawatt hour
HCI	Human capital index
IEA	International Energy Agency
IISD	International Institute for Sustainable Development
ILO	International Labour Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
kg	Kilogram
km	Kilometer
LCU	Local currency unit
MAFF	Ministry of Agriculture, Fisheries and Forestry
MER	Market exchange rates
MW	Megawatt
NDP	Net domestic product
NPV	Net present value
OECD	Organisation for Economic Co-operation and Development
ONS	UK’s Office for National Statistics
PPA	Power purchase agreement
PPP	Purchasing power parity
PWT	Penn World Tables
RVM	Residual value method
SAU	Sea Around Us
SCC	Social cost of carbon
SDGs	Sustainable Development Goals
SEEA	System of Environmental-Economic Accounting
SEEA-CF	System of Environmental-Economic Accounting Central Framework
SEEA-EA	System of Environmental-Economic Accounting Ecosystem Accounting
SNA	System of National Accounts
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNFC	United Nations Framework Classification for Resources
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United States dollar
WTP	Willingness to pay

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Executive Summary

WHY MEASURING CHANGES IN THE WEALTH OF NATIONS MATTERS

While many countries across the globe have experienced strong economic growth and improvements in human development outcomes over the last quarter of a century, natural resources continue to be degraded and overexploited, calling the sustainability of that growth into question. The main yardstick typically used to assess economic progress is gross domestic product (GDP), which measures the level of domestic productive activity. Real GDP grew by more than 50 percent between 1995 and 2020, accompanied by significant reductions in global poverty and improvements in educational and health outcomes.[1] However, natural resources, such as land, experienced widespread overexploitation and degradation during the same period.[2]

The world needs a broader metric to assess the sustainability of economic development. As natural resources become scarcer and reach critical levels due to climate change and biodiversity loss, the growth potential of an economy and its resilience to shocks will be adversely affected.[3] Yet GDP does not measure such sustainability concerns. Sir Partha Dasgupta likened this to a soccer team that only measures success as goals for and ignores goals against.

A minimum requirement for sustainable development is that real wealth per capita does not decline.[4] If wealth can be measured comprehensively, per capita wealth changes will reflect the rise or fall of production and subsequent consumption opportunities passed on to future generations.[5] "Production and consumption" should be understood broadly here to include things that humans benefit from every day, many of which are "produced" by nature. In this sense, a nation's wealth includes a large portfolio of assets, ranging from clean air, to a local forest that allows for a walk in the woods, to medical staff treating the sick in a hospital, to oil fields where hydrocarbons are pumped out of the ground. Changes in real wealth per capita should capture changes in the real value of these assets and the production and consumption opportunities they support.

Strategic decisions to measure national wealth must take account of considerable data and conceptual constraints. At present, it is not possible to measure all the assets that support a nation's production and consumption opportunities. Consider the example of water. Measuring and valuing water is challenging and contentious due to its physical characteristics, the way it is regulated and used within the economy, and the fact that it is an essential good.[6] Moreover, its value may be partly embedded in other assets, such as agricultural land or hydropower. It is not feasible to account for the value of water. This is also true for many other assets.

In measuring wealth, methodological boundaries need to be respected, but existing systems limit the extent of the balance sheet. Measures of wealth should be coherent and aligned with the internationally accepted accounting standards of the System of National Accounts (SNA) and the System of Environmental-Economic Accounting (SEEA), each of which restrict what can be measured within the asset boundary. Natural resources such as land, forests, waters, or

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[1] See Kharas and Dooley (2022), UNESCO (2020), and data from the World Development Indicator, the Wittgenstein Center, and the UN Statistics Division.

[2] See, for example, Cohen et. al (2019), Drupp and Hänsel (2021), and Rad et. al (2021).

[3] For example, Smulders and van Soest (2023) show that with limited substitutability in factors of production economic growth is ultimately determined by the slowest-growing factor. Limited substitutability between natural assets and other factors of production, such as labor, can also shape economic resilience against natural shocks. Karayalcin and Onder (2023) show that the magnitude of the original impact (fragility) and the speed of the subsequent recovery (resilience) are determined by the ability of the economy to reallocate inputs between sectors, which will in turn be driven by their degree of substitutability as well as institutional characteristics, such as economic openness and property rights in natural assets.

[4] Aligned with the definition of the World Commission on Environment and Development (1987).

[5] There is a well-established literature in economics on sustainable development, including Solow (1993), Dasgupta and Maler (2000), Arrow et al. (2004), and Dasgupta (2021).

[6] See Vardon et al. (2024) for a detailed discussion of how water could be integrated into wealth accounting.

wild animals are included in balance sheets provided that an institutional unit exercises effective ownership rights over them, and economically benefits from them. Resources such as the atmosphere, the high seas, or the mineral or fuel deposits that cannot be extracted economically at present are excluded.

The World Bank's The Changing Wealth of Nations (CWON) program provides the most comprehensive wealth database currently available. It builds on and goes beyond the asset boundary of the SNA and SEEA[7] to better capture the changing future opportunities nations face. Most of the assets covered in CWON—such as factories, intellectual property, urban land, and roads (*produced capital*); fossil fuel, mineral, and metal reserves (*nonrenewable natural capital*); agricultural land, forests, and fish stocks (*renewable natural capital*); and net foreign assets—are within the SNA asset boundary. Others, like renewable energy assets, will be included in the SNA starting in 2025.[8] Over time CWON has expanded the SNA asset boundary to include key SEEA ecosystem accounts,[9] such as non-timber forest ecosystem services[10] and shoreline protection services provided by mangroves,[11] as well as the value of investments in the labor force (*human capital*). While there is currently not systematic measurement for the latter within the SNA, the lifetime income approach used by CWON[12] is one of the statistical approaches recommended as a wealth extension in the 2025 SNA update.[13]

Changes in CWON's real wealth per capita metric can provide insights on the sustainability of economic progress, complementing GDP. CWON's wealth measure includes a broad portfolio of market and non-market assets and can track how this asset base evolves over time. For example, real wealth per capita will increase if more workers enter the labor force or if the same workers upgrade their skills, if forests grow, or new commercially recoverable minerals are discovered. However, it will decline if fish stocks are overfished, machinery degrades, or the reserves of fossil fuels are depleted. By monitoring per capita trends in real GDP and real wealth together, it is possible to assess whether growth in GDP is achieved by growing or shrinking the productive base of the economy.

This fifth edition builds on CWON'S tradition of incremental improvements. Each update of its global database improves the methodology and expands asset coverage. This edition further aligns nominal wealth estimates for key assets with SNA and SEEA concepts and valuation principles,[14] and adds more metals and hydropower assets.[15] Moreover, the real wealth estimates are now computed using a chained Törnqvist volume index instead of a price-based deflator in line with international best practice.[16] In this approach, the relative changes in the physical assets of a nation, such as the number of workers in the labor force, are weighted by their relative economic importance as measured by their shares in nominal wealth.[17]

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[7] The United Nations Environment Programme (UNEP) is the second global initiative that is producing a database of wealth estimates (UNU–IHDP and UNEP 2012; UNU–IHDP and UNEP 2014; Managi and Kumar 2018; UNEP 2023). While there are similarities in country and temporal coverage, there are methodological differences, including in the valuation concepts, assets coverage, estimates of human capital, and assumptions used to estimate wealth.

[8] Renewable energy assets are not yet part of the SNA. However, guidelines for their inclusion, which were developed for the previous CWON report (World Bank 2021), were endorsed as part of the 2025 SNA revision process and are available at: https://unstats.un.org/unsd/nationalaccount/aeg/2022/M21/M21_14_WS11_Renewable_Energy_Resources.pdf.

[9] Note that the asset boundary of the SEEA Central Framework is fully aligned with the SNA asset boundary, while the SEEA Ecosystem Accounting goes beyond it.

[10] Some of these non-wood forest ecosystem services may be in the SNA (for example, non-wood forest products like mushroom harvesting), while others (such as recreation) are not.

[11] The value of shoreline protection services may be partially attributed to property value in the SNA to the extent that housing prices account for climate risks.

[12] This approach was developed by Jorgenson and Fraumeni (1989, 1992a, 1992b), and is used by several statistical offices to produce satellite accounts for human capital, such as Canada or the United Kingdom.

[13] Guidelines on how the dimensions of education, human capital, and labor could be included in the SNA were developed and endorsed as part of the ongoing 2025 SNA revision process and are available at: https://unstats.un.org/unsd/nationalaccount/RAdocs/ENDORSED_WS4_Labour_Human_Capital_Education.pdf.

[14] The goal of the methodological improvements is to align further with the internationally endorsed concepts and valuation principles from the SNA and SEEA. For example, the user cost of capital is now estimated directly in the resource rent calculations for nonrenewable natural capital and rent, and wage forecasts are removed from agricultural land and human capital valuations.

[15] This edition adds cobalt, lithium, and molybdenum, increasing the CWON coverage from 10 to 13 metals and minerals.

[16] In the national accounts space, all real measures (including real GDP) are in fact volume indexes expressed in the prices of a reference year. The new approach is very similar to the methods currently used for real GDP in advanced economies like Canada or the United States (except that they use a slightly different index form, a chained Fisher volume index).

[17] This is true for composite asset portfolios, for example, when computing total real wealth including all assets, or for the main asset categories, but not single homogenous assets. Chapter 2 provides more detail on the implementation of the chained Törnqvist volume index. For more technical details on the properties of the Törnqvist index, refer to Dumagan (2002) and Diewert (1992).

GLOBAL TRENDS IN REAL WEALTH PER CAPITA

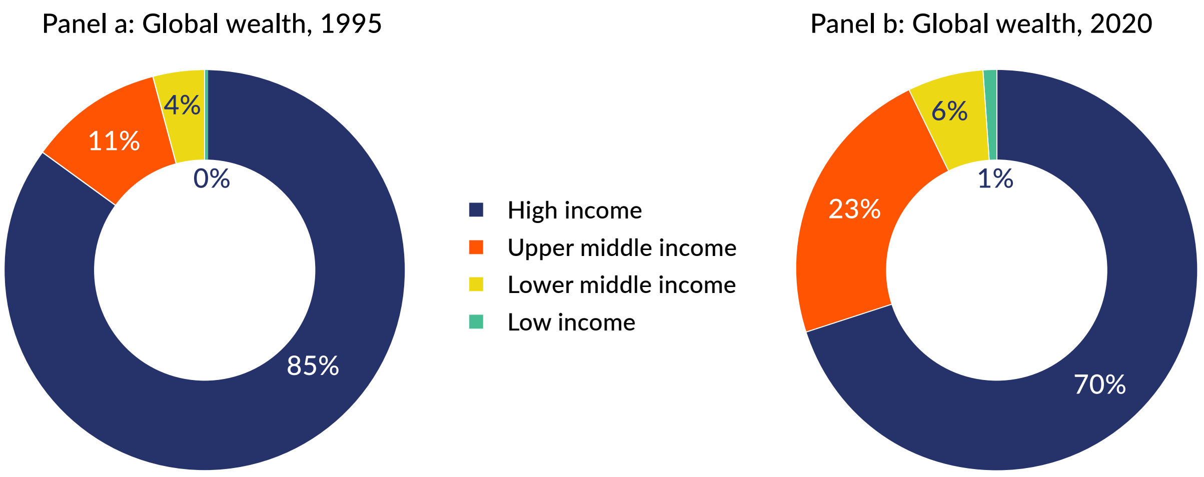
Wealth remains highly concentrated in rich countries, with significant disparities persisting across income groups. High-income countries make up more than two-thirds of total wealth in nominal terms in 2020, while upper-middle-income countries constitute nearly a quarter (Figure ES.1, Panel b).

Low-income and lower-middle-income countries, home to half of the world's population, account for just 7 percent of global wealth. There is no evidence that this wealth gap has been closing: while upper- and lower-middle-income countries were able to nearly double their share in global wealth, the wealth share of low-income countries has largely remained below 1 percent since 1995.

Trends in real wealth per capita are crucial for assessing the sustainability of economic progress. Real wealth per capita has grown in all regions due to significant increases in human and produced capital (Figure ES.2a), which were driven by rapid urbanization and the growing number of women participating in the labor market. The growth trend is particularly pronounced in the Middle East and North Africa region (97 percent) and Latin America and the Caribbean (66 percent). This growth is largely attributed to substantial rises in human capital (82 percent and 61 percent, respectively) and produced capital (138 percent and 83 percent, respectively) in these regions, but has not resulted in substantial increases in their share in global wealth (which stood at 4 percent and 3 percent, respectively, in 2020).

FIGURE ES.1

Distribution of global wealth in nominal terms, by income group, 1995 and 2020



Source: World Bank staff estimates.

Note: Wealth in nominal terms is measured in current US dollars. Global wealth per income group is computed as the sum of nominal wealth for all countries in that income group for 1995 and 2020, respectively. Wealth shares are then computed relative to the global sum of wealth across all countries in the sample for 1995 and 2020, respectively, and are reported in percent.

FIGURE ES.2A

Trends in real wealth per capita, by region, 1995–2020 (1995=100)

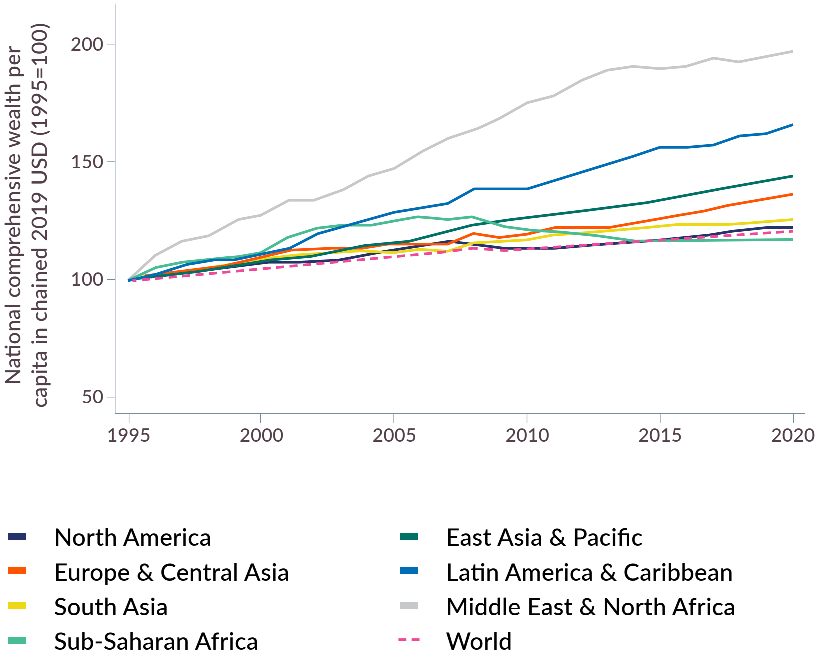
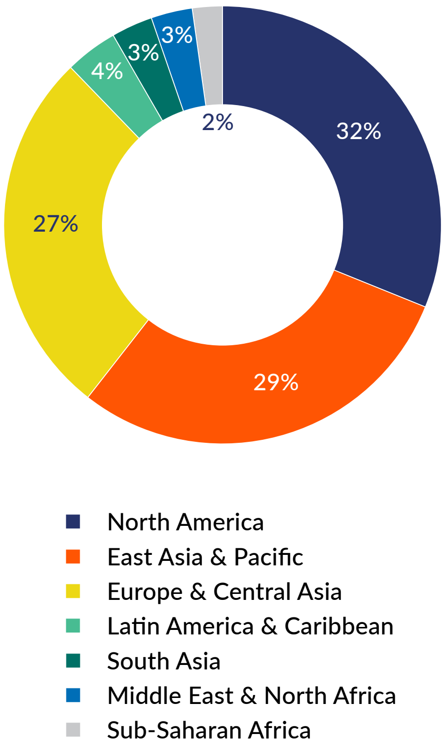


FIGURE ES.2B

Nominal wealth shares, by region, 2020



Source: World Bank staff estimates.

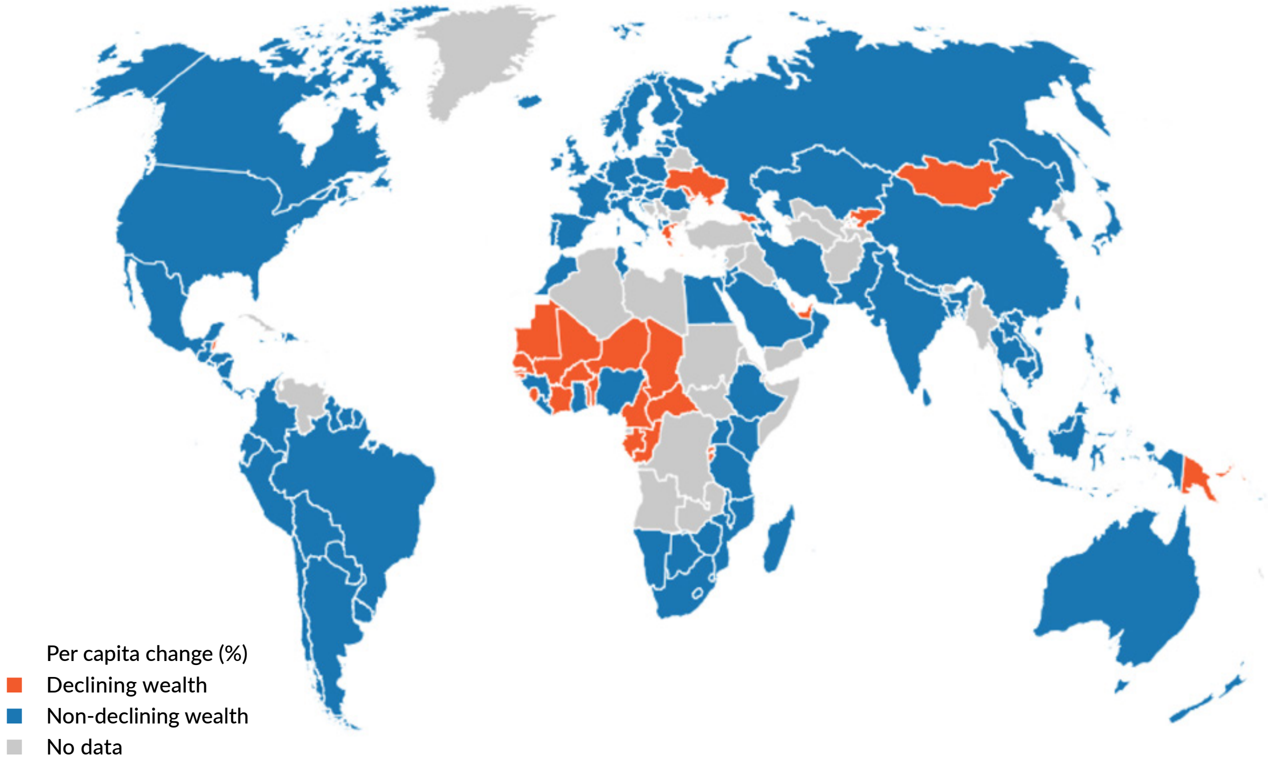
Note: Real wealth per capita is computed using the Törnqvist volume index. For the relative volume changes, chained Törnqvist volume indexes are used for produced capital, nonrenewable and renewable natural capital, human capital, and net foreign assets (for net foreign assets, the nominal asset value is deflated using consumer price index (CPI)). The weights are calculated using their respective nominal asset value relative to nominal wealth. The Törnqvist volume index for wealth is then chained with a base year of 2019 and real wealth is computed using the nominal wealth estimate for 2019. Regional wealth per capita is computed as a sum of real wealth for the countries in the region divided by the regional population. Changes in real wealth per capita for each region are reported relative to 1995 (set equal to 100). Nominal wealth is measured in current US dollars and shares are reported in percent.

The accumulation of real wealth in some regions, notably Sub-Saharan Africa, has not grown at the same speed as their respective populations. While there were periods of growth in real wealth per capita in Sub-Saharan Africa, such as between 2000 and 2005, there has been a stagnating trend since then, with the region making up just 2 percent of global wealth.

While two-thirds of the 151 countries in the sample experienced growth in real wealth per capita between 1995 and 2020, 27 countries experienced declines or saw little change. The decline in low-income countries signals that economic progress is unsustainable. One possible driver of these observed trends could be conflict, as 40 percent of these countries are also classified by the World Bank as affected by fragility, conflict, and violence (FCV).

FIGURE ES.3

Countries with declining and non-declining real wealth per capita, 1995–2020



Source: World Bank staff estimates.

Note: Percent changes in real wealth per capita are computed for the 1995–2020 period. This figure distinguishes between countries that experienced declining wealth (percent change < 0) vs. non-declining wealth (percent change >= 0) during this period, but does not compare wealth per capita nominal values directly. As discussed throughout the report, non-declining wealth per capita is a minimum requirement for sustainable economic growth, although not a sufficient condition.

WHAT IS DRIVING CHANGES IN REAL WEALTH PER CAPITA?

The trends in real wealth per capita are driven by changes in the asset portfolio relative to population growth, with starkly different trends across asset categories. There are four main asset categories that make up CWON's wealth measure: produced capital, nonrenewable natural capital, renewable natural capital, and human capital. Human capital, which makes up the largest share of nominal wealth (Figure ES.4b), has increased by about 9 percent in per capita terms relative to 1995, as shown in Figure ES.4a. Produced capital increased by 47 percent in per capita terms between 1995 and 2020. Nonrenewable natural assets slightly declined in per capita terms over the same period. This is the most volatile asset category, affected by changes in the underlying asset base, technological innovations, and price fluctuations.

Renewable natural capital, which should be able to regenerate itself if managed sustainably, has declined by more than 20 percent in per capita terms over the past quarter of a century. It is important to note that this trend and its 6 percent share in global wealth is likely an underestimate, as data and conceptual concerns limit the ability to measure and value this component.

FIGURE ES.4A

Trends in global wealth per capita, by asset category, 1995–2020 (1995=100)

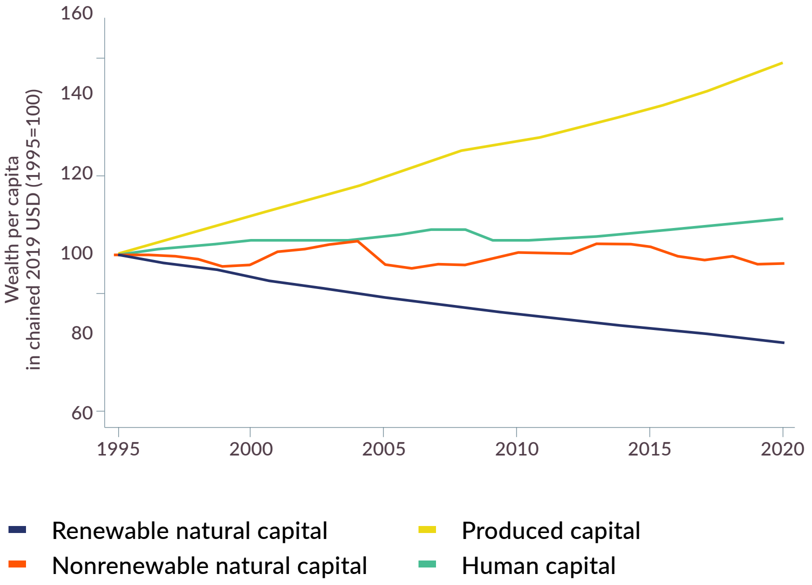
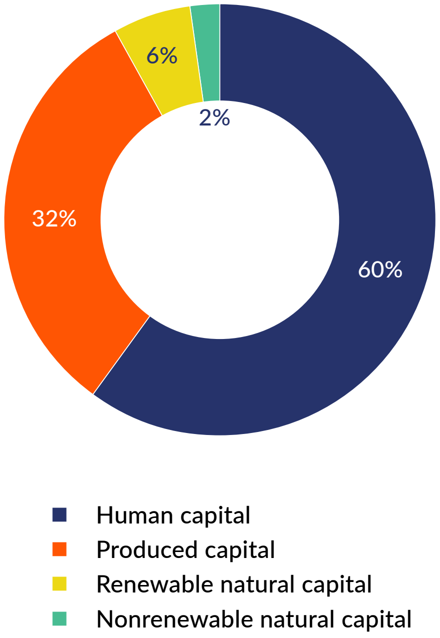


FIGURE ES.4B

Nominal wealth shares, by asset category, 2020



Source: World Bank staff estimates,

Note: Real wealth per capita by asset category is computed using the Törnqvist volume index. For the relative volume changes, physical measurements of the assets in each asset category are used. The weights are calculated using their nominal asset value relative to the nominal value of their respective asset category. The Törnqvist volume index for each asset category is then chained with a base year of 2019 and the real value of each asset category is computed using the nominal value of each asset category for 2019. The global real value of each asset category (measured in chained 2019 US dollars) is computed by summing across all countries and dividing by the global population. Changes in real comprehensive wealth per capita for each asset category are reported relative to 1995 (set equal to 100). Nominal wealth is measured in current US dollars and shares are reported in percent.

There is a significant variation in the level of decline in renewable natural capital wealth per capita across regions and assets. Sub-Saharan Africa and the Middle East and North Africa region have experienced the largest declines (around 40 percent), with South Asia losing about a third. These declines are driven by population growth and overexploitation across almost all renewable natural resources included in this report, such as forests, marine fish stocks, and mangroves. The value of marine fish stocks has experienced the most dramatic decline, dropping by more than 45 percent since 1995 (Figure ES.5a). Other renewable natural capital components—such as agricultural land, which is the most important component of renewable natural capital (73 percent of its global value), and non-timber forest recreation ecosystem services (12 percent)—have experienced similar though less dramatic declines. Notably, renewable energy from hydropower—a new addition to CWON—experienced an increase of 23 percent over the same 25-year period, making up 7 percent of the overall value of renewable natural capital. However, renewable energy assets such as solar, wind, and geothermal assets were not included in this edition due to data limitations.

FIGURE ES.5A
Trends in renewable natural capital per capita, by asset, 1995–2020 (1995=100)

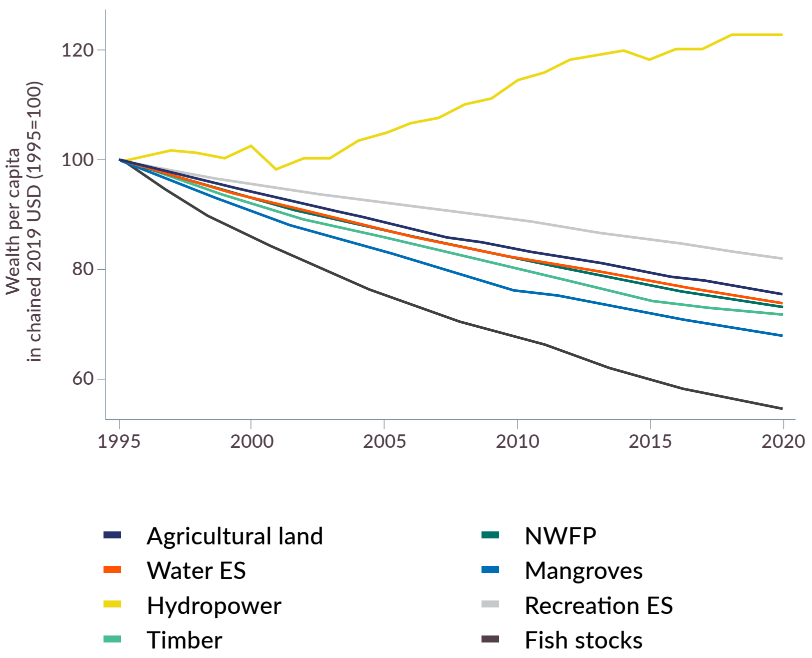
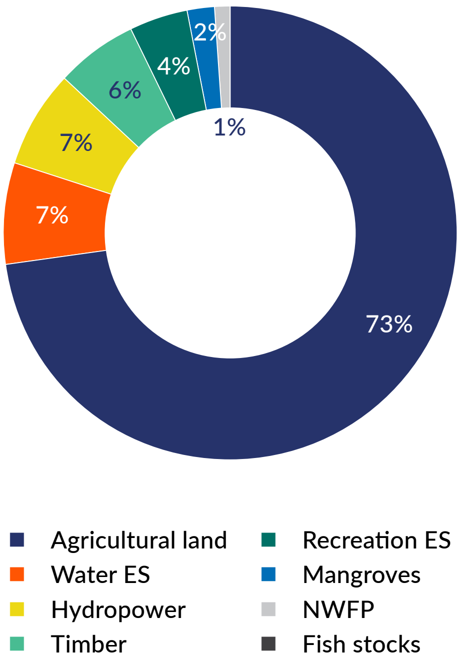


FIGURE ES.5B
Nominal wealth shares for renewable natural capital, by asset, 2020



Source: World Bank staff estimates.
Note: Real wealth per capita for each asset is computed using the Törnqvist volume index. The relative volume changes use physical measurements of agricultural land (in square km), timber (in hectares), mangroves (in hectares), non-wood forest ecosystem services (in square km), hydropower (in GWh), and fish stocks (in tons). No weighting is used for measuring individual assets in real terms. The Törnqvist volume index for each asset is then chained with a base year of 2019 and the real value of each asset is computed using the nominal asset value for 2019. The global real value of each asset (measured in chained 2019 US dollars) is computed as the sum of real wealth for each asset divided by the global population. Changes in the real asset value per capita are reported relative to 1995 (set equal to 100). ES = ecosystem services. NWFP = non-wood forest products. Nominal wealth is measured in current US dollars and shares are reported in percent.

Globally, nonrenewable natural capital—spanning oil, natural gas, coal, and metals and minerals—decreased by 2.5 percent in per capita terms between 1995 and 2020, with a small increase in oil wealth offset by declines in coal, natural gas, and minerals (Figure ES.6a). The low-carbon transition is likely to affect these estimates in the short to medium term. However, large decreases in carbon-intensive fossil fuels (except for coal) have not yet been observed, which still make up nearly 60 percent of the global value of nonrenewable natural capital (Figure ES.6b).

Rapid urbanization and industrialization in high-income and emerging economies have led to substantial growth in produced capital wealth. On average, there is about 47 percent more produced capital per capita in the world than there was in 1995, and it has accumulated faster than population growth in all the regions (Figure ES.7a). Produced capital per capita in South Asia has experienced an astonishing expansion, increasing by nearly 500 percent, albeit from a very low level. Most of the produced capital assets are concentrated in North America, Europe, and East

FIGURE ES.6A

Trends in nonrenewable natural capital per capita, by asset, 1995–2020 (1995=100)

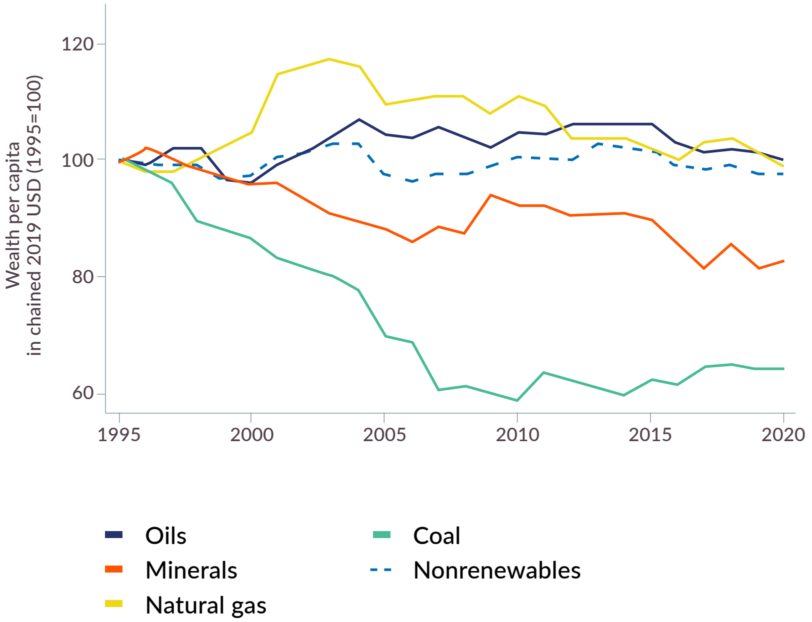
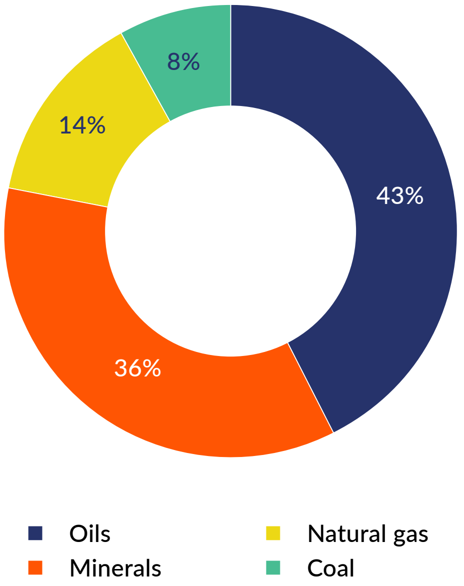


FIGURE ES.6B

Shares in nominal wealth for nonrenewable natural capital, by asset, 2020



Source: World Bank staff estimates.

Note: Real nonrenewable natural capital per capita is measured in chained 2019 US dollars. For details on the computation of real wealth per capita per asset refer to the notes for Figure ES.5. The relative volume changes use physical measurements of oil (in barrels), gas (in terajoules), coal (in tons), and minerals (in tons). Nominal wealth is measured in current US dollars and shares are reported in percent.

Asia, which make up 94 percent of the global value and have experienced lower but steady growth rates. Sub-Saharan Africa experienced the lowest growth rates. Although the region made significant strides in accumulating produced capital wealth—matching that of other regions with a 129 percent increase over 25 years—rapid population growth led to a modest 17 percent increase from 1995 to 2020.

Human capital, which accounted for 60 percent of the world's total wealth value in 2020, has grown consistently for the past 25 years due to increasing labor force participation and higher returns to education. The share of human capital in total wealth (measured in nominal terms) generally increases as countries achieve higher levels of economic development. The world's real human capital per capita increased by 9 percent between 1995 and 2020, but there are contrasting trends across regions (Figure ES.8a).[19]

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[19] The growth rate in global human capital per capita is so low, since there have been small increases in the share of global human capital in South Asia (from 2.6 percent in 1995 to 3.2 percent in 2020) and Sub-Saharan Africa (from 1.1 percent to 1.8 percent). While these changes are small in absolute terms, they are able to depress the global growth rate in human capital per capita due to significant differences in the value of human capital relative to richer regions. For example, North America has a nominal value of human capital that is 60 times higher than in South Asia and Sub-Saharan Africa.

FIGURE ES.7A

Trends in produced capital per capita, by region, 1995–2020 (1995=100)

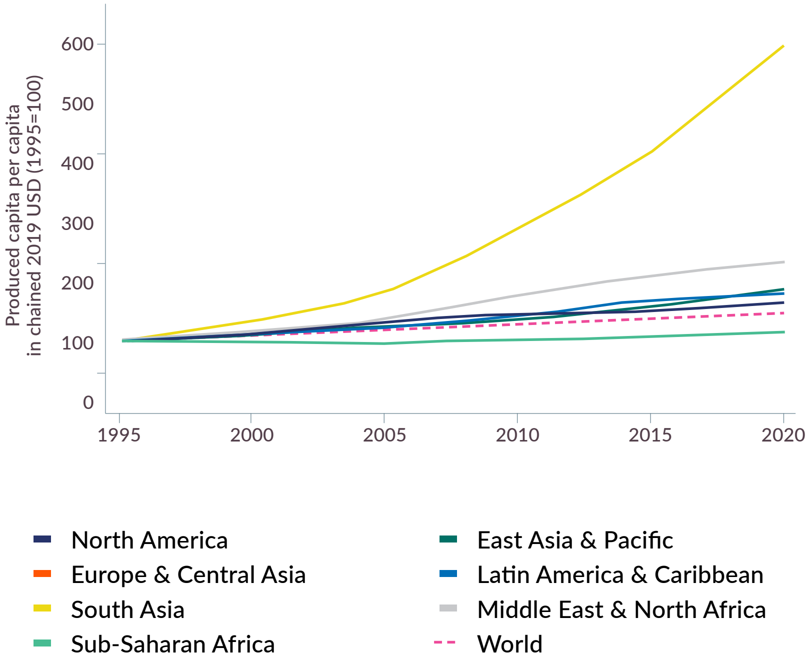
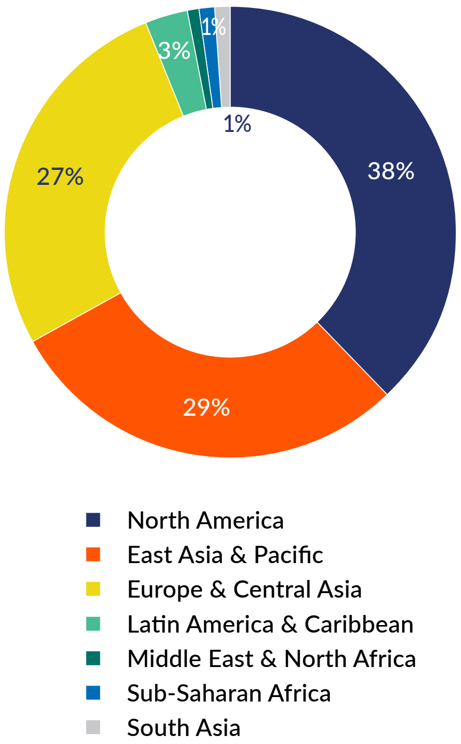


FIGURE ES.7B

Nominal wealth shares for produced capital, by region, 2020



Source: World Bank staff estimates.

Note: Real produced capital per capita is measured in chained 2019 US dollars. For details on the computation of real wealth per capita for produced capital refer to the notes for Figure ES.5. For the relative volume changes, the following data are used: capital stock estimates from the Penn World Table 10.0 and urban land area estimates based on World Bank staff estimates using data from the United Nations Population Division's World Urbanization Prospects, the Food and Agriculture Organization (FAO), and the Center for International Earth Science Information Network. The weights are calculated using their nominal asset value relative to the nominal value of produced capital. Nominal wealth is measured in current US dollars and shares are reported in percent.

Human capital is concentrated in the high- and upper-middle-income countries of North America, Europe and Central Asia, and East Asia and the Pacific, as shown in Figure ES.8b. These regions have experienced modest growth rates, with, for example, 12 percent in North America and 16 percent in East Asia and the Pacific. In contrast, the Middle East and North Africa, and Latin America and the Caribbean regions show much larger increases of 82 percent and 62 percent, respectively, over the same period, albeit from a much lower starting point.

Estimates show a significant disparity between the male and female shares of human capital. Unfortunately, little progress was made toward greater gender parity in human capital between 1995 and 2020. Globally, women accounted for only 37 percent of human capital in 2020—only 2 percentage points up from 1995. 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. The differences between regions are even more striking.

FIGURE ES.8A

Trends in human capital per capita, by region, 1995–2020 (1995=100)

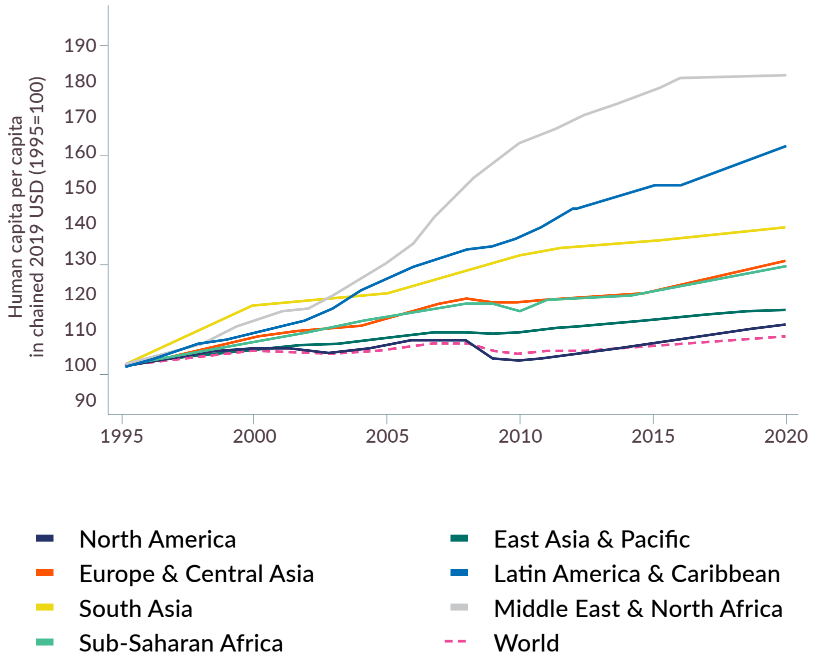
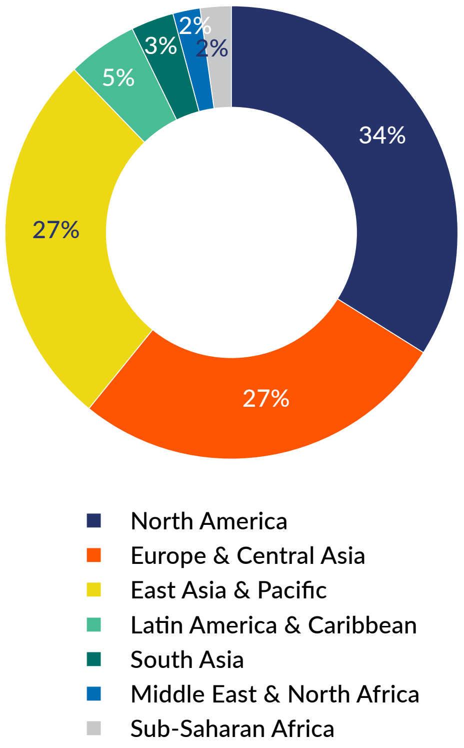


FIGURE ES.8B

Nominal shares of human capital, by region, 2020



Source: World Bank staff estimates.

Note: Real human capital per capita is measured in chained 2019 US dollars. For details on the computation of real wealth per capita for human capital refer to the notes for Figure ES.4. For the relative volume changes, labor force numbers disaggregated by gender from the International Labor Organization (ILO) are used, which are scaled by the human capital index from the Penn World Tables to proxy for the average human capital per worker. The weights are calculated using their nominal asset value relative to the nominal value of human capital. Nominal wealth is measured in current US dollars and shares are reported in percent.

For example, in South Asia, women represented 15 percent of human capital in 2020, marking a 2 percent decline from 1995. In contrast, 44 percent of human capital was attributed to women in Latin America and the Caribbean. South Asia's large gender gap is mostly caused by a male-dominated labor force and barriers that prevent women from attaining similar economic opportunities as men (World Bank 2023b).

While the different asset components of wealth have been on starkly different trajectories, this has so far not yet acted as a brake on growth. Rising productivity and the ability to substitute one scarcer asset for a more abundant one have so far been able to offset the erosion of the asset base, most notably with regards to renewable natural capital. It remains an open question how long this trend can continue considering that natural capital continues to be overexploited and is becoming scarcer. The extent to which limited substitutability could be accounted for within CWON through, for example, relative price adjustments or differentiated discount rates is further explored in chapter 4. Indicative estimates suggest that such adjustments would substantially increase the share of renewable natural capital in overall wealth.

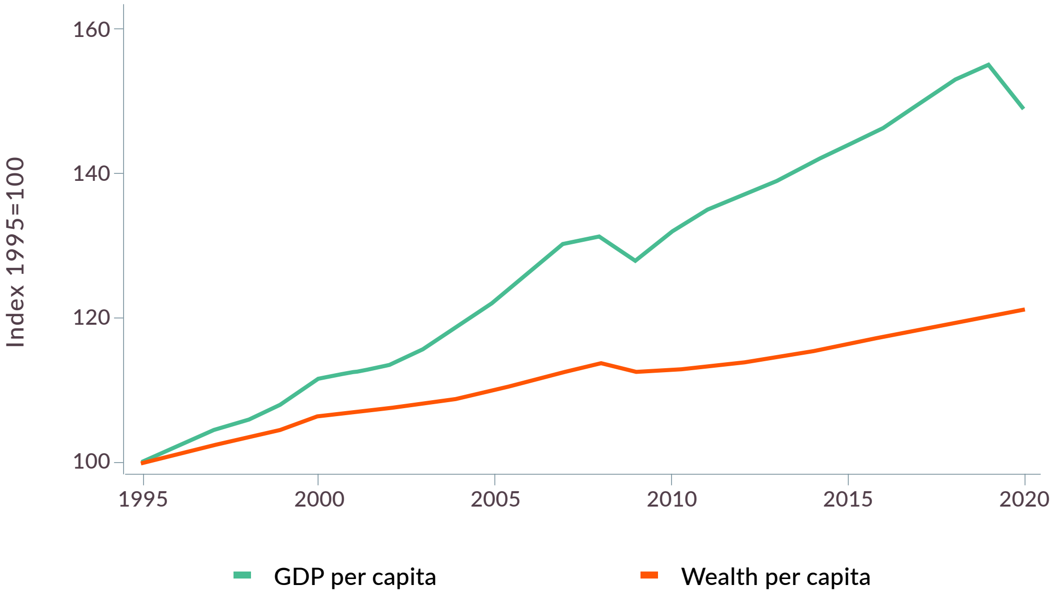
TRENDS IN REAL WEALTH AND GDP PER CAPITA

Globally, real wealth per capita increased by about 21 percent between 1995 and 2020. This contrasts with the observed increase in real GDP per capita of about 50 percent over the same period (Figure ES.9). Changes in real wealth per capita are driven by changes in the real asset base, capturing the accumulation and depletion of assets over time. That is, real wealth per capita will decline as capital is used up, degraded, or destroyed in the process of generating output. Current GDP, on the other hand, often increases when asset depletion accelerates; for example, when forest is clearcut and timber is sold. CWON provides researchers and analysts with the most comprehensive, transparent, and rigorous global data time series of the wealth of nations to conduct such analysis.

A more granular look at the data reveals that global wealth trends mask large and persistent differences across income groups and FCV status. Rich countries are becoming wealthier, while poor and conflict-affected nations are in a downward spiral of low growth and wealth depletion. This is further illustrated in Figure ES.10, which maps changes in real GDP per capita to changes in real wealth per capita. While most countries are experiencing growth in both real GDP and wealth per capita, 15 percent of countries are currently experiencing positive GDP per capita growth rates while their real wealth per capita declines. For these countries, it will be critical to continue building their asset base to ensure a sustainable growth path. The rest of the countries either show declines in both GDP and real wealth per capita or did not experience growth in GDP per capita but appear to accumulate real wealth per capita.[20] These observed trends warrant a more detailed empirical analysis to explore what is driving these differences.

FIGURE ES.9

Changes in global real GDP and wealth per capita, 1995–2020 (1995=100)



Source: World Bank staff estimates.

Note: Real GDP per capita is measured in constant 2015 US dollars from the World Bank's World Development Indicators database (NY.GDP.PCAP.KD) and real wealth per capita is measured using the Törnqvist volume index and is reported in chained 2019 US dollars.

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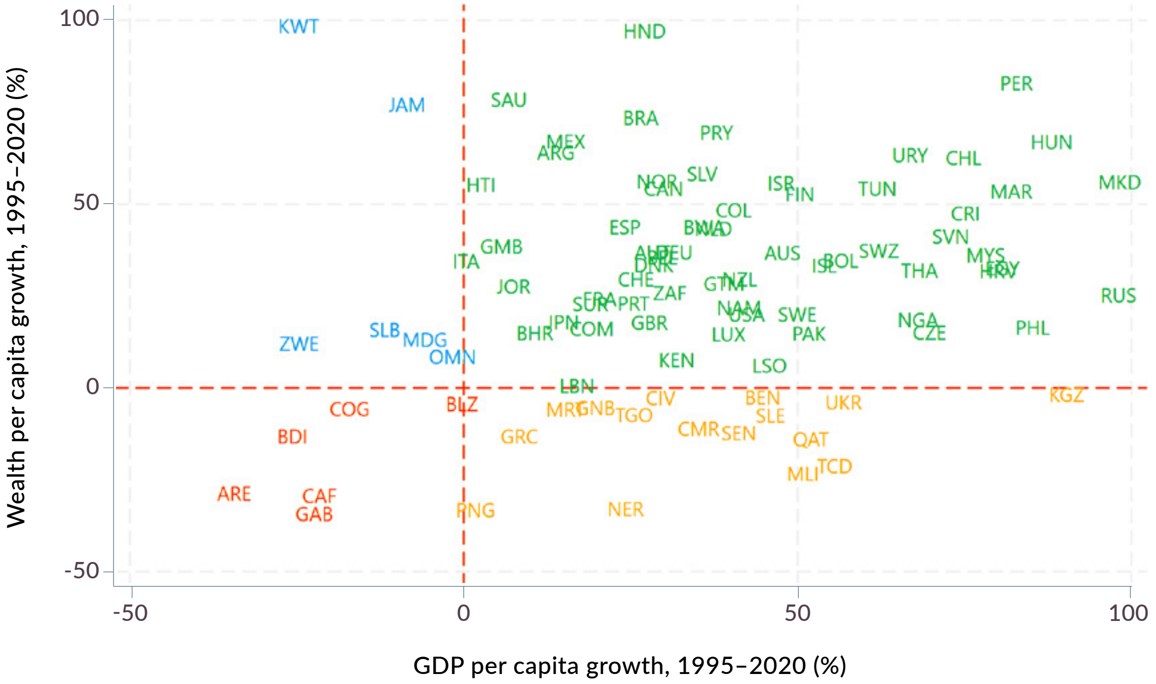
[20] This group of countries includes Jamaica, Kuwait, Madagascar, Oman, the Solomon Islands, and Zimbabwe.

FIGURE ES.10

Cumulative GDP per capita growth vs. cumulative wealth per capita growth, 1995–2020



Source: World Bank staff estimates.

Note: The sample was restricted to growth rates less than 100 percent. The scatter plot shows country codes. Countries in green have increasing GDP and wealth per capita, countries in blue have declining GDP per capita but increasing wealth per capita, countries in orange have increasing GDP per capita but declining wealth per capita, countries in red have declining GDP and wealth per capita.

CONCLUSIONS

CWON's estimates of real comprehensive wealth per capita can be used to assess the sustainability of a nation's economic progress and complement GDP. By producing these estimates, the World Bank addresses an important data gap, as all countries produce GDP, but few produce wealth estimates. Importantly, this edition offers countries the possibility to construct customized national-level wealth estimates by building on the CWON methodology. As part of the World Bank's reproducibility initiative, the entire statistical code and input data[21] used to generate the nominal and real wealth estimates of the CWON database will be publicly released on the World Bank's website. This unprecedented access will provide users with the opportunity to use more granular, country-level input data and modify assumptions as needed to support their own sustainability analysis.

CWON's long-term ambition is to support the analysis of sustainability. At this stage, the extent to which this ambition has been fulfilled or even exceeded is an open analytical question. The analysis of sustainability is unavoidably constrained by which assets are included on the CWON balance sheet and the precision with which they are measured.[22]

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[21] For licensed data, dummy datasets will be made available.

[22] For a detailed discussion of these issues, refer to chapter 1.

Over time, the assets included have progressively expanded and the measurement has considerably improved. While it is important to acknowledge that important gaps in the coverage remain due to data and measurement constraints, the CWON balance sheet is nonetheless the most comprehensive wealth database available today, in terms of coverage of assets, countries, and time series, aligned where possible with the internationally accepted statistical standards and guidelines in the SNA and SEEA. This alignment not only ensures methodological rigor, but also coherence with standard economic measures like GDP.

While this edition has implemented several critical methodological innovations, more work is needed to advance CWON as a regular, ongoing statistical program. To achieve this, it will be critical to take a more systematic approach to defining the asset boundary for the wealth estimates based on the assets that fall within the SNA and SEEA boundaries, with appropriate extensions (for example, for human capital). This will enable the CWON program to stay aligned with the SNA and SEEA standards, while also going beyond them in meaningful and appropriate ways. Future updates should aim to selectively expand the boundaries, for example, to also include the value of renewable energy resources, while maintaining a balance between progressive expansion and the stability of the asset boundary. A common challenge for the statistical and economic communities will be to explore viable approaches to assigning monetary values for assets that provide essential economic services to humans in the context of heavily distorted or missing markets.

Lastly, it is important to note that CWON provides baseline estimates in line with endorsed statistical guidance. This means the wealth estimates reflect the current policy environment and market expectations and do not account for possible impacts of future policy actions or changes in market conditions due to, for example, climate change. To explore these questions and "what if" scenarios, researchers will have the opportunity to adapt the CWON input data and source code to change assumptions or adopt alternative methodologies in line with their requirements. This will enhance use applications, which can range from customized wealth estimates at the country level to projections of policy-contingent scenarios, as illustrated in CWON 2021 with simulations for fossil fuel and renewable energy assets. CWON thus serves as a flexible, transparent, and reproducible database available for stress-testing and empirical research.

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I.

Tracking Wealth to Monitor Economic Progress

1 Wealth as an Indicator of Sustainability

MAIN MESSAGES

- The world seeks a headline indicator to help assess aggregate progress on the 17 Sustainable Development Goals (SDGs) and sustainability more broadly.
- To achieve such a measurement, a robust discussion is needed about expanding national economic statistics "beyond GDP" (gross domestic product). Despite GDP's important role in measuring production and income, it is widely recognized to be an insufficient measure of progress and national sustainability.
- Whether progress is sustainable, that is, whether future generations will have at least the same production and consumption opportunities as the current generation, can be assessed by looking at changes in real wealth per capita. Constant or increasing wealth per capita—measured comprehensively to include produced, human, and natural capital, as well as net foreign assets—is thus an important indicator of sustainability.
- While almost all countries measure GDP, few countries produce wealth measures. Those that do generally do not measure wealth comprehensively by including natural and human capital.
- The Changing Wealth of Nations (CWON) database aims to fill this data gap by producing a comparable and consistent measure of change in real wealth per capita for 151 countries. These estimates are aligned, where possible, with the System of National Accounts (SNA) and the System of Environmental-Economic Accounting (SEEA) balance sheets to ensure comparability with other standard macroeconomic measures, such as GDP.
- CWON aspires to measure wealth comprehensively, and its measurement has gradually expanded with each edition as new data and statistical standards have become available, and more sophisticated methodologies have been adopted. The current coverage includes key assets from the SNA balance sheet and critical ecosystem assets covered by the SEEA Ecosystem Accounts. CWON also goes beyond the current SNA standards to include human capital.

INTRODUCTION

There is no more evocative phrase in economics than "the wealth of nations." Indeed, some would argue these were the first words written in the field. Despite Adam Smith coining the phrase nearly 250 years ago, economists continue to struggle to measure the wealth of nations and how it changes through time. This challenge facing economists and statisticians today is much like the challenge mariners once faced in measuring longitude at sea—yet measurement of where you are, and how your position is changing, is important for "steering the ship."

Decision-makers have long put sustainability and the possible enhancement of economic welfare at the center of the policy discourse. This includes the many national and international conversations around the SDGs[23] the beyond GDP agenda,[24] and the importance of mainstreaming nature into decision-making processes.[25] To inform such decisions requires evidence and data, which ultimately depend on some form of measurement.

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[23] https://sdgs.un.org/goals.

[24] https://unsceb.org/topics/beyond-gdp.

[25] See, for example, the G7 Environment Ministers' Communiques of 2023 (https://www.meti.go.jp/press/2023/04/20230417004/20230417004-1.pdf) and the G7 Science Ministers' Communique in 2023 (https://www8.cao.go.jp/cstp/kokusaiteki/g7_2023/230513_g7_communique.pdf), as well as the Global Biodiversity Framework (https://www.cbd.int/gbf/targets/14/).

The World Bank's CWON program is one of the pioneering efforts in this field, endeavoring to produce a global database of comparable and consistent estimates of comprehensive wealth[26] for nearly two decades. These monetary estimates draw on internationally endorsed concepts and valuation principles from the SNA and related standards. They have been updated and expanded with each new edition as new data sources, measurement techniques, and guidance have become available. CWON aspires to measure wealth as comprehensively as possible with each iteration, while acknowledging that there are still important forms of wealth that have not yet been accounted for.

The CWON report series has elevated changes in real wealth per capita, which helps measure whether economic progress is sustainable, as a complementary metric to GDP. Changes in real wealth per capita over time, if measured comprehensively, are proportional to changes in welfare (Arrow et al. 2004; Dasgupta 2001; Polasky et al. 2015).[27] A minimum requirement for sustainable development is that welfare, and thus comprehensive wealth, does not decline. Measuring change in comprehensive wealth is therefore an essential building block in measuring and managing sustainable economic development.

This chapter lays out why it is important to measure changes in real wealth per capita and the theory of using this metric to assess sustainability. Next, it discusses how progress can be measured within the current context of the SNA and the extent to which national statistical offices currently (do not) record changes in real wealth. It then discusses the importance of an appropriate asset boundary, and price and value concepts in developing wealth estimates. The final two sections discuss how the CWON program implements these in the context of a global wealth accounting exercise and the extent to which these choices align with the SNA. It concludes with a summary of how the current CWON wealth measure can be interpreted.

THE IMPORTANCE OF THE CHANGE IN WEALTH IN THE MEASUREMENT OF SUSTAINABILITY

Policy definitions of sustainable development usually start with the World Commission on Environment and Development (1987) definition: "meeting the needs of the current generation without compromising the ability of future generations to meet their needs."[28] Economists have developed two complementary measurement approaches to put this definition into practice: a wealth- and an income-based approach. The first approach focuses on assessing changes in the state of the world by measuring changes in stock values like real wealth per capita. As long as real wealth per capita does not decline, welfare per capita does not decline, which is a necessary condition for development to be sustainable (Arrow et al. 2004; Arrow, Dasgupta, and Maler 2003; Dasgupta 2001). The second approach, well synthesized by Sefton and Weale (2006), focuses instead on the flow measures for consumption or real income, which could be thought of as a modified version of per capita net domestic product, or net national income. Provided these flow measures are not negative, welfare per capita does not decline either, and development is sustainable. In theory, the flow measures should balance the change in the stock measure, though this is not necessarily the case in practice due to differences in scope and measurement challenges.

CWON uses the economic measure of capital to assess wealth, emphasizing the importance of balance sheet measures that are often missing from official national statistics. Wealth in this context can either be an input into production or a store for future production or consumption opportunities. For example, cash savings can be used in the future to pay workers or procure raw materials. Similarly, natural capital, such as land fertility, standing forests, and fish stocks, can be used today or saved for future production.[29] To value capital or wealth, one needs to compute the expected net present value of future income that this capital generates as comprehensively as possible. For example, harvesting

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[26] Comprehensive wealth estimates include produced, human, renewable natural, and nonrenewable natural capital as well as net foreign assets.

[27] This is even the case when welfare is not maximized in a second-best world (Lipsey and Lancaster 1956).

[28] See also Pezzey (1992) and Solow (1993).

[29] In the case of renewable resources, the resource stock can also grow on its own, increasing in quantity and potentially total value over time.

fish is not purely the production from fishing labor and fishing boats[30]—it also involves production by the natural capital itself, in this case the fish stock. Foregoing a fish harvest today could increase production and, ultimately, consumption opportunities for tomorrow. Wild fish stocks should therefore be treated as wealth (Fisher 1906) and included in any comprehensive measurement of capital.[31]

The change in wealth is an important sustainable development indicator, as it reflects the rise or fall of production and subsequent consumption opportunities passed on to future generations relative to those of the current generation (Arrow et al. 2004). As long as future production and consumption opportunities are not diminished relative to those of the present, development may be sustainable. Production and consumption should be understood broadly here to include the non-market goods and services humans benefit from every day, many of which are "produced" by nature, such as breathable air, clean water, food, weather regulation, and recreation. A nation's wealth includes a large portfolio of assets, ranging from a local forest, which contributes to the service of a "walk in the woods," to the medical staff treating the sick in a hospital, and the oil field where crude oil is pumped out of the ground. Changes in real wealth per capita are expected to capture changes in the real value of these assets and the production and consumption opportunities they support.

Yet, how those production (and, ultimately, consumption) opportunities change depends on the exact definition of sustainability used and, in particular, the extent to which substitution opportunities are assumed to vary over time. On one end of the spectrum, the "strong sustainability" definition implies that future generations need at least the same physical quantities of capital, at least up to broad asset classes like natural and produced capital, as generations today (Dietz and Neumayer 2007). Under such assumptions, agricultural production, for example, could only be maintained with the same combination of land, labor, and machinery used today. This definition effectively rules out substitution opportunities across and within asset classes in the present, or those that may emerge through innovations in future. From a measurement perspective, a society would only pass a sustainability test if all enumerated capital stocks do not physically decline.[32] The other end of the spectrum is known as "weak sustainability," which is often interpreted as accepting the possibility of endless substitution or innovation.[33] In that case, development is weakly sustainable, as long as overall wealth (per capita) increases. For example, a decline in natural capital can be compensated for through investments in produced or human capital.

The reality is likely somewhere in between these two definitions, where some substitution and innovation possibilities exist, but where there are also complementary relationships, especially between natural and produced capital (see Cohen et al. 2019; Rouhi Rad et al. 2021). Take the example of fish (natural capital) and fishing boats (produced capital). If fish and fishing boats were perfect substitutes, then the scarcity of fish would not impede sustainable growth if the production of boats increased sufficiently. But, in reality, these are imperfect substitutes (and in fact are complementary), which means the scarcity of fish would further impede economic growth. A practical solution is offered by Barbier (2011), who suggests measuring actual substitution or "capital sustainability." Building on Hicks' concept of real income, the idea is that changes in real wealth are measured after accounting for, and removing, measured substitution effects. That is, changes in production or consumption due to substitutions need to be separated from those that are truly changes in opportunities, which should then be recorded as changes in real wealth associated with economic income effects.

Changes in real wealth per capita, if measured comprehensively, are then proportional to changes in welfare, if appropriate prices are used, as shown by Dasgupta (2001).[34]

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[30] Production measurements such as GDP attribute all the value added to the labor of fishermen and the returns of fishing capital like boats.

[31] Indeed, when fish stocks are managed, they should be recorded on the internationally agreed SNA non-financial balance sheets (European Commission et al. 2009). However, few countries actually do so. Furthermore, Fenichel and Abbott (2014) show that even when fisheries are not rationalized there is a positive marginal value (price) of a fish stock that can be imputed from fishery rents and ecological information in a way consistent with the traditional production boundary.

[32] In the strictest sense, this definition rules out the use of any nonrenewable resource. This creates a contradiction because by eliminating all use of nonrenewables, there is no reason not to use them up.

[33] This is often operationalized as a partial equilibrium saving rule that is linear in exogenous prices (Pearce and Atkinson 1993).

[34] Dasgupta caveats this by pointing out that per capita measures are important when populations are changing. His approach generally aligns with other attempts to develop theoretical measures of changes in national income (for example, Sefton and Weale 2006).

Limits to substitution and even complementary relationships are reflected in how prices respond to changing scarcity (Yun et al. 2017). The challenge lies in separating the income and substitution effects to identify the changes in real wealth. In addition, it is critical to capture substitution patterns over time, as substitution opportunities are affected by changes in the relative scarcity of assets. Whether a change-in-capital approach ultimately implies strong or weak sustainability (or somewhere in between) and whether it provides a welfare measure comes down to the prices used, the capital stocks included, whether enough capital stocks are included to consider the wealth measurement comprehensive, and how wealth is aggregated. These points are discussed in more detail in the next section.

Regardless of the theoretical framework, only changes in wealth matter for measuring sustainability—not levels. The absolute level of total wealth of a nation, which could be conceived as the net present value of all future production opportunities, is not a well-defined quantity in this context. The total value of wealth would be determined by removing all those future opportunities, at which point the nation itself would cease to exist.[35] However, the future opportunities available to a country do change. It is this change that can be measured with changes in wealth, even if the entirety of wealth—the total size of future opportunities—cannot be measured. It is intentional that this report series is called *The Changing Wealth of Nations* and not *The Absolute Wealth of Nations.*

MEASURING ECONOMIC PROGRESS BEYOND GDP

To understand why it is important to go beyond GDP to measure sustainability, it is helpful to understand the current system of economic measurement. The seeds for a comprehensive national approach to measuring production, income, and wealth were planted in the wake of the Great Depression of the 1930s, and solidified during World War II, when the world realized that it needed a systematic approach for measuring economic cycles and mobilizing industrial output. This desire has evolved into an elaborate accounting system, the SNA, which features GDP—the market value of all final goods and services produced within a country's boundaries over a period—as the primary indicator.

The SNA is conceived as a stock-flow-stock system, grounded in a double entry accounting system,[36] that can comprehensively track production and income flows leading to changes in wealth in an internally consistent accounting framework. Over time, the objective of national accounts has evolved to aid governments with monetary and fiscal questions, such as the setting of monetary policy, the development of budgetary forecasts, and the projection of business conditions. This enabled the development of statistics, such as GDP. In contrast, the SNA's prescribed dimensions related to wealth have had substantially slower uptake across countries, especially those with limited statistical capacity.

GDP's success as a headline indicator has led to it often being described as providing a "birds-eye view" of the economy. Because it is nearly universally available and adheres to standards assuring international comparability, GDP is widely used as a benchmarking and reference statistic, even for purposes for which it was not designed (Jorgenson 2018). Indeed, the international standards acknowledge that GDP and the associated gross national income (GNI)[37] are not the best measures of national income (European Commission et al. 2009, paragraph 16.51), but are often used out of context as such. Perhaps in part because of this misuse, GDP has been frequently criticized for three specific shortcomings that are critical for sustainability (Stiglitz, Sen, and Fitoussi 2010). First, GDP ignores the loss of capital. Second, it draws the boundary of the economy too narrowly and excludes important services that are not produced through market mechanisms. Third, the supply-use tables used to construct GDP may misattribute value.

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[35] In fact, zero wealth is never defined in the theory, as this would imply no future opportunity—in a global sense it is the end of the world. It is, of course, true that individuals experience different levels of financial wealth and enjoy different qualities of life, which may speak to meeting the needs of current generations. Yet, a person's wealth is not truly zero until he or she is dead, which is the only state of no opportunity—but also the state of no person.

[36] Since these entries are recorded for both sides of a transaction, it is effectively a double-double entry system.

[37] GNI comprises GDP and the net receipts of primary income (compensation of employees and property income) from nonresident sources. It is also summarized from the SNA.

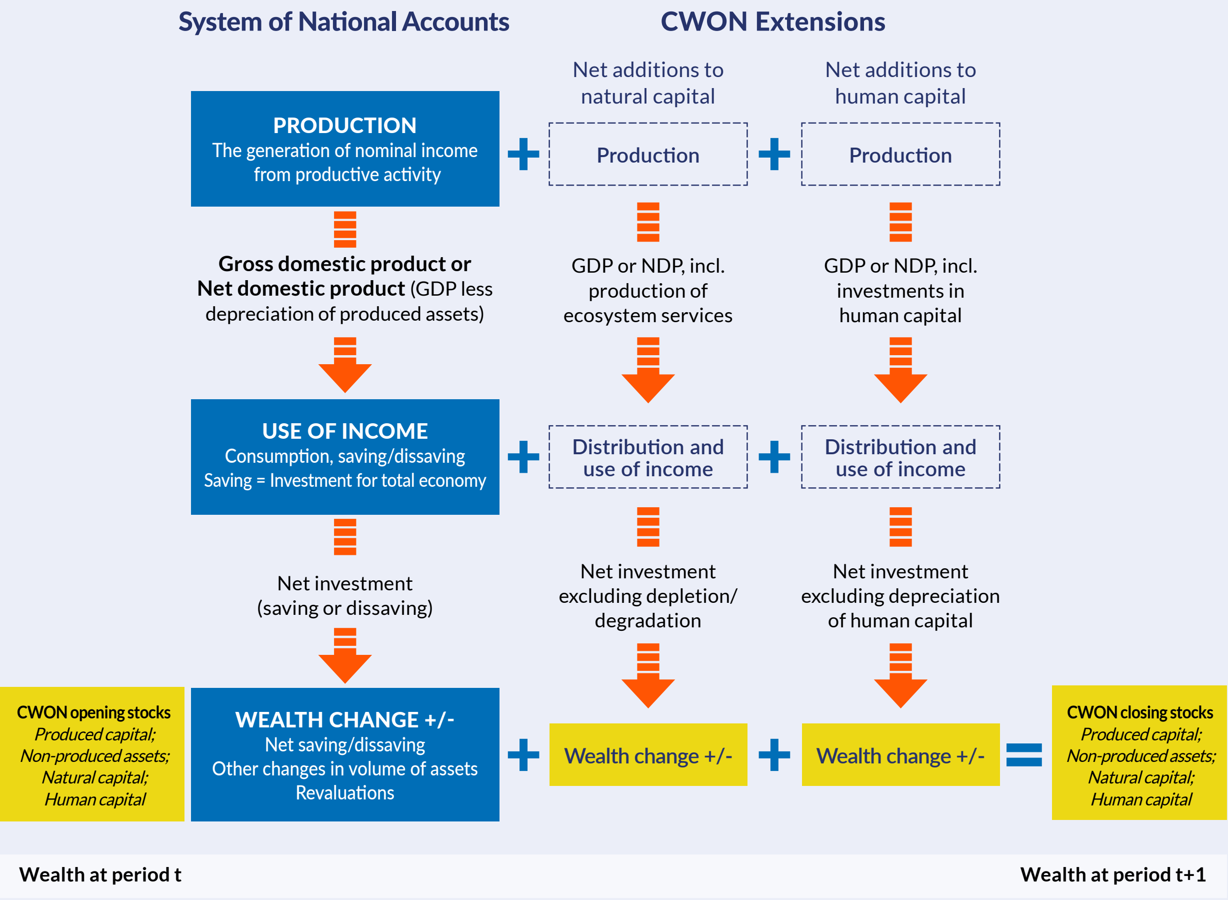
BOX 1.1
THE RELATIONSHIP BETWEEN GDP AND COMPREHENSIVE WEALTH

One approach to understanding the relationship between GDP and comprehensive wealth is to start by spelling out standard accounting relationships underlying economic statistics.

Concepts and accounting relationships

The SNA framework is underpinned by a stock-flow-stock model, illustrated in Box Figure 1.1.1. Economic flows underlying the change in wealth from one period to the next implicitly include a variety of elements. It is important to note that CWON is restricted to measuring only stocks, that is, wealth, and does not articulate all the flows underlying changes in wealth. The diagram below presents a high-level characterization of a full (theoretical) stock-flow-stock framework. In doing so, it makes explicit the conceptual relationship between GDP flows and wealth stocks.

BOX FIGURE 1.1.1
GDP vs. wealth in the context of CWON



Standard SNA concepts of GDP and wealth follow a logical flow of interrelated processes presented in a set of integrated "accounts," beginning with production and ending with wealth accumulation (or decumulation). GDP represents the flow of productive activity inside a country's geographic boundaries in a given period. This productive activity generates income as returns to the factors of production, broadly characterized as labor and capital. In the context of standard indicators, natural capital in the form of natural resources and land is also able to be measured.

A subsequent account shows how income from production is used, for example, for consumption or saving, and how it is allocated among economic actors. The key result of these processes linking production with wealth accumulation is net saving/dissaving, which at the economy level equals net investment. "Net" means excluding the using up (depreciation, depletion, or degradation) of capital either through its ongoing use in production or obsolescence. Unlike gross measures such as GDP or gross investment flows, net measures like NDP or net investment flows can be directly related to changes in wealth.

In addition to net saving or dissaving, the volume of assets and thus wealth can change for other reasons. For example, losses due to climate events such as hurricanes, wildfires, or floods can result in important reductions to the asset base. Additions falling into this category include discoveries of new natural resource reserves, or improvements in technologies for energy and minerals, which make the extraction of previously "uneconomic" reserves more viable. Additions could also stem from changes in management or renewable resources, such as restricting the harvest of managed wild fish.

Extended measures in the CWON

Standard SNA measures of production (GDP) and national wealth have well-defined boundaries. The latter are limited to produced capital and non-produced capital, such as natural resources, including land. In the context of wealth extensions in CWON, if wealth is extended, integrated measurement would also imply extended measures of GDP and other related statistics in the logical flow of accounts.

With the extension of standard wealth measures to include new aspects of natural capital (such as renewable energy and ecosystem assets) and human capital, the difference between gross and net production or investment increases even further. For example, net production or investment should also include the depletion of natural resources, or, in the case of ecosystems, the depletion and degradation of ecosystem assets that are not currently in the GDP/SNA asset boundary. Standard SNA measures do not currently account for these production costs. Similarly, measurements of human capital investments need to be based on the expected returns to education and training expenditures, along with many other less easily quantifiable factors, such as the development of skills and aptitudes on the job or outside the formal education system, since education is often rationed rather than procured in the market.

CWON produces extended wealth measures that capture net savings, other volume changes, as well as revaluations for a more comprehensive set of assets than currently considered by GDP. While a full articulation of flows contributing to CWON wealth changes would undoubtedly provide useful insights, developing such a framework would be an ambitious exercise, the feasibility of which has yet to be fully examined.

For example, if green spaces increase a home's value, this increase may be accounted for, but it is misattributed as coming from sticks and bricks only.

This focus on restricted production concepts, such as GDP and GNI, is inappropriate if the goal is to assess the sustainability of economic progress. GDP is the amount of new goods and services produced in a period with a defined beginning and end. Only gross investment matters in this context to ensure that consumption plus gross investment equate to production (after adjusting for trade). How capital generates value in situ does not matter for GDP. Wealth, on the other hand, is the net present value of all future production opportunities. The capital that wealth measures is the stock embodying those future opportunities, which is in turn a function of net investment. Wealth thus captures traditional depreciation (as does net domestic product or NDP), but it goes beyond that to also account for volume changes for other reasons, such as natural disasters or discoveries of fossil fuel reserves. Wealth also accounts for revaluations that reflect changes in the productivity of a given asset or changing supply and demand dynamics. Moreover, wealth typically provides a more comprehensive measurement of the assets relevant to production, including natural and human capital (Box 1.1 outlines in more detail the relationship between GDP, NDP, and wealth).

The main challenge is that other summary measures from the SNA, such as NDP and wealth, are less developed and country-level data are often lacking. To address this data gap, the World Bank launched The CWON program in 2006. The early CWON work drew heavily on the pioneering empirical work of Hamilton and Clemens (1999) on genuine savings rates. The immediate goal was to produce a metric that would elevate the importance of environmental assets and shift the discourse in the national accounting community toward measuring not only production and income, but also capital and changes in wealth. In addition, it was an opportunity to revisit the production and asset boundaries used in standard national accounts measures, and to push beyond those boundaries to better capture the changing opportunities nations may face.

This renewed attention on comprehensively measuring all asset categories, most notably human and natural capital, was necessary to provide the full national income or changes in wealth measures required to monitor true progress. Eighteen years later, the international statistical community has made progress in the development of internationally accepted statistical standards and guidelines through the System of Environmental-Economic Accounting (SEEA), covering natural capital assets (stocks) and ecosystem services (flows) (United Nations et al. 2021; United Nations et al. 2014). The use of natural capital accounting has increased across the globe, with more than 90 countries producing SEEA accounts (UN 2023a). Notable examples include Australia, Botswana, Canada, Costa Rica, India, Indonesia, Lao People's Democratic Republic, Mexico, the Netherlands, the Philippines, South Africa, Uganda, the United Kingdom (UK), and Zambia. In addition, while there is no systematic measurement for human capital in the SNA, alternative approaches are recommended as a wealth extension in the 2025 SNA update.[38] These have been successfully implemented by Canada and the UK.

Moreover, there are growing international calls to find economic and sustainable development measures beyond GDP. The UN Secretary General has made going beyond GDP in national economic statistics a priority and has recognized comprehensive wealth accounting by the World Bank as one of the key initiatives in this area.[39] There are also calls for better accounting for the environment and natural capital in macroeconomic statistics, including from the G7,[40] the

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[38] Guidelines on how the dimensions of education, human capital, and labor could be included within the SNA were developed and endorsed as part of the ongoing 2025 SNA revision process and are available at: https://unstats.un.org/unsd/nationalaccount/RAdocs/ENDORSED_WS4_Labour_Human_Capital_Education.pdf.

[39] https://unsceb.org/valuing-what-counts-united-nations-system-wide-contribution-beyond-gross-domestic-product-gdp.

[40] This includes a G7 Communique of 2018 (https://www.international.gc.ca/world-monde/assets/pdfs/international_relations-relations_internationales/g7/2018-06-09-summit-communique-sommet-en.pdf), the G7 Environment Ministers' Communiques of 2022 (https://www.bundesregierung.de/resource/blob/974430/2044350/84e380088170c69e6b6ad45dbd133ef8/2022-05-27-1-climate-ministers-communique-data.pdf?download=1) and 2023 (https://www.meti.go.jp/press/2023/04/20230417004/20230417004-1.pdf), and the G7 Science Ministers' Communique of 2023 (https://www8.cao.go.jp/cstp/kokusaiteki/g7_2023/230513_g7_communique.pdf).

G20,[41] and leading academics,[42] and through targets set by the SDGs[43] and the Global Biodiversity Framework.[44] In addition, many national statistical offices have work programs going beyond GDP, and there are similar initiatives in the corners of government responsible for economic planning and progress. Examples include Canada's Census of the Environment, the Dasgupta Review published by the UK's Treasury (2021), or the United States' (2023) *National Strategy for Natural Capital Accounting and Associated Environmental Economic Statistics.*

THE RIGHT STUFF: THE WEALTH ACCOUNTING BOUNDARY

The SNA draws specific boundaries on what should be counted and what should be excluded from its accounts. GDP and national accounts use potential market transactions as the starting point to define the production boundary and then adjust to account for other types of economic transactions, ultimately including a wide range of goods and services. For example, GDP includes production traded in the market,[45] as well as production that may not involve a cash transaction, such as bartered goods, and subsistence agriculture, hunting, and fishing.[46] Goods and services that cannot be traded after being produced or that were not produced on contract for payment are excluded, even if they are economically important (European Commission et al. 2009).[47]

The SNA guidelines differentiate between the production boundary and the asset boundary, recognizing that assets may still contribute to production despite not being traded themselves. The SNA asset boundary includes all the traded durable assets of the production boundary, such as machines (*produced capital*), and recognizes that non-produced and non-financial assets, like forests and wild fish stocks (*natural capital*), may be inside the asset boundary. The SNA states, "many environmental assets are included within the SNA," (European Commission et al. 2009, paragraph 1.46) in reference to these non-produced and non-financial assets. A criterion for these assets to be within SNA bounds is that private individuals, companies, or governments[48] seek to manage these assets in a way that will contribute to future production. However, this limits the set of environmental assets that can be included, as resources such as the atmosphere or high seas are excluded. Similarly, goods and services provided by uncultivated forests or the mineral or fuel deposits that cannot be extracted economically at present are not assigned a value.

The SEEA system bolsters the SNA's measurement of the environment and natural resources. The SEEA Central Framework (CF) provides guidance on measuring the value of environmentally related services and natural assets that are within the SNA production boundary (United Nations et al. 2014). Before the SEEA-CF, many of these services and assets had been included in the SNA at least since 1993, but statistical offices had been unsure how to measure them.[49] For example, the SNA uses wild fish stocks within a country's exclusive economic zone and managed by a government on behalf of a commercial fishing community as an example of inbounds uncultivated biological assets. The SEEA Ecosystem Accounting (EA) expands the asset boundary to include environmental services, such as environmental health benefits and recreation, and associated natural assets (United Nations et al. 2021), as has long been called for, or assumed already done, by the economics literature.[50]

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[41] This includes the G20 Data Gaps Initiative of the International Monetary Fund (https://www.imf.org/en/News/Seminars/Conferences/g20-data-gaps-initiative), which has identified several climate change indicators and national accounts distributions as critical data gaps for policy.

[42] Prominent examples include Arrow et al. (2004), Fleurbaey (2009), Guerry et al. (2015), Jorgenson (2018), and Hulten and Nakamura (2022).

[43] Sub-indicator 15.9.1b of the SDGs tracks the integration of biodiversity into national accounting and reporting systems following SEEA principles (https://unstats.un.org/sdgs/metadata/files/Metadata-15-09-01.pdf).

[44] Target 14 of the Global Biodiversity Framework calls for the integration of the multiple values of biodiversity into decision-making at all levels, including in national accounting (https://www.cbd.int/gbf/targets/14/).

[45] Examples include manufactured machines, agricultural output, rental services of homes and hotels, books, movies, paid domestic work and paid childcare services, timber harvested from forests, commercially caught fish from the ocean, and services produced by governments and non-governmental organizations.

[46] Technically, even cutting firewood or growing vegetables in a home garden is within the production boundary, but these are seldom measured in practice.

[47] These include cooking one's own meals, cleaning one's own house, and caring for one's own children, health supporting services provided by the environment, and leisure activities for which individuals do not pay. However, GDP does include one measure of services produced by households: the imputed value of owner-occupied housing services.

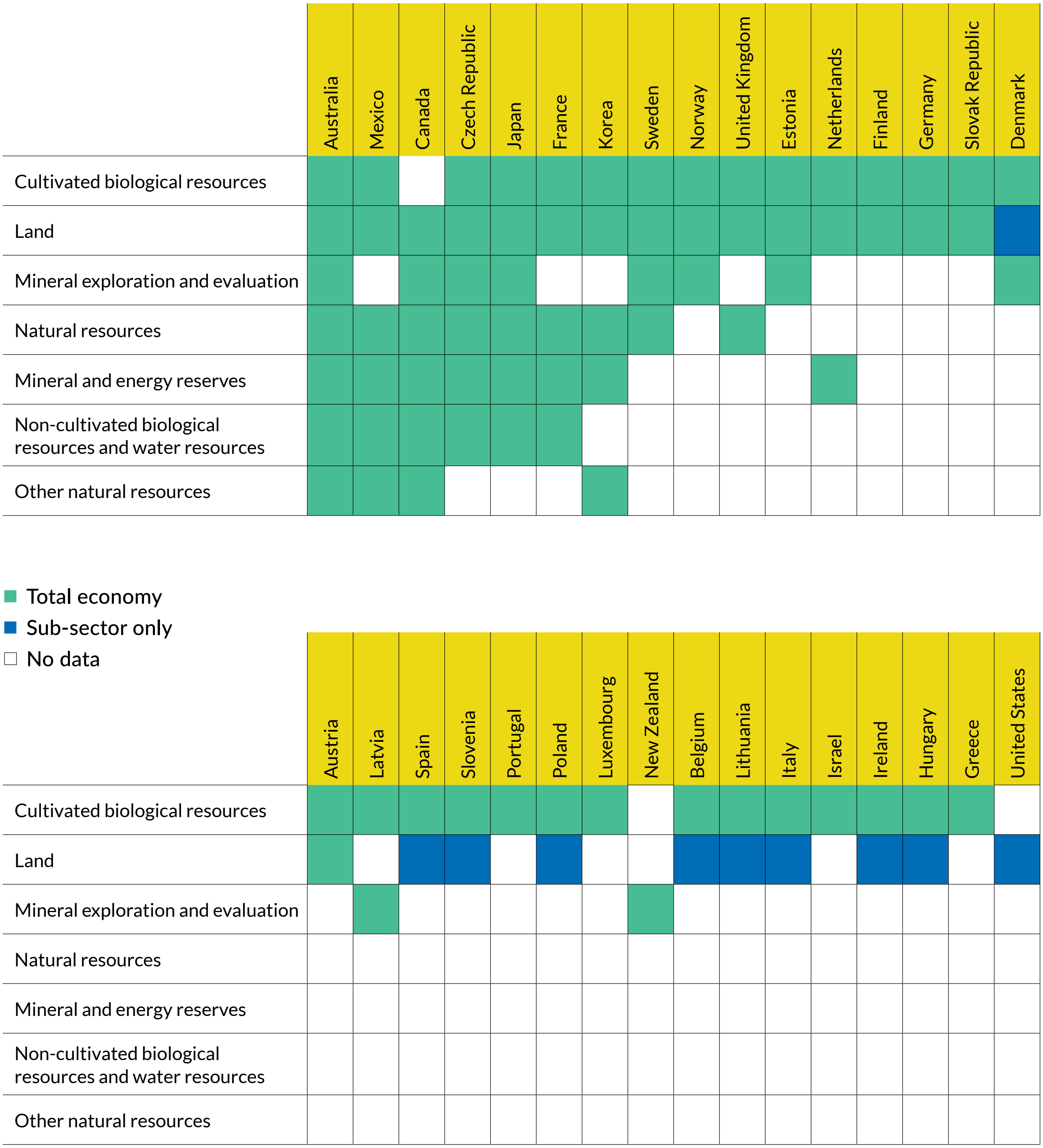
[48] For example, the SNA clarifies that this includes when a government manages the asset on behalf of a user group.

[49] In fact, the SEEA-CF and the SNA's guidance on natural resources exposed many boundary cases, and substantial confusion remains.

[50] See, for example, Weitzman (1976); Sefton and Weale (2006); Dasgupta (2001); Hamilton and Clemens (1999).

FIGURE 1.1

Coverage of "natural capital" on the official SNA non-financial balance sheet for OECD countries



	Australia	Mexico	Canada	Czech Republic	Japan	France	Korea	Sweden	Norway	United Kingdom	Estonia	Netherlands	Finland	Germany	Slovak Republic	Denmark
Cultivated biological resources	🟩	🟩	☐	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Land	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟦
Mineral exploration and evaluation	🟩	☐	🟩	🟩	🟩	☐	☐	🟩	🟩	☐	🟩	☐	☐	☐	☐	🟩
Natural resources	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	☐	🟩	☐	☐	☐	☐	☐	☐
Mineral and energy reserves	🟩	🟩	🟩	🟩	🟩	🟩	🟩	☐	☐	☐	☐	🟩	☐	☐	☐	☐
Non-cultivated biological resources and water resources	🟩	🟩	🟩	🟩	🟩	🟩	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other natural resources	🟩	🟩	🟩	☐	☐	☐	🟩	☐	☐	☐	☐	☐	☐	☐	☐	☐

🟩 Total economy
🟦 Sub-sector only
☐ No data

	Austria	Latvia	Spain	Slovenia	Portugal	Poland	Luxembourg	New Zealand	Belgium	Lithuania	Italy	Israel	Ireland	Hungary	Greece	United States
Cultivated biological resources	🟩	🟩	🟩	🟩	🟩	🟩	🟩	☐	🟩	🟩	🟩	🟩	🟩	🟩	🟩	☐
Land	🟩	☐	🟦	🟦	☐	🟦	☐	☐	🟦	🟦	🟦	☐	🟦	🟦	☐	🟦
Mineral exploration and evaluation	☐	🟩	☐	☐	☐	☐	☐	🟩	☐	☐	☐	☐	☐	☐	☐	☐
Natural resources	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Mineral and energy reserves	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Non-cultivated biological resources and water resources	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other natural resources	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Source: Authors' compilation based on OECD data (https://stats.oecd.org/).
Note: Cultivated biological resources and mineral exploration and evaluation are considered produced assets. The remaining asset classes are classified as non-produced assets. OECD countries Chile, Iceland, Colombia, Türkiye, and Switzerland are not included in the chart since they do not report any data.

However, in practice, the coverage of SNA assets by national statistical offices is often incomplete, and SEEA accounts are not compiled by countries in ways that align with the rest of the economy. Not all countries currently measure non-financial produced capital and even fewer countries produce natural capital accounts or non-produced asset accounts on a regular basis (UN 2023) or compile these assets on national balance sheets.[51] For example, 43 countries report balance sheet data to the Organisation for Economic Co-operation and Development (OECD) going back to 2000.[52] The OECD data cover seven categories of produced (two) and non-produced (five) capital that might be considered natural capital.[53] Most of the 43 countries have missing data, especially for natural capital (Figure 1.1). Five countries—Chile, Iceland, Colombia, Türkiye, and Switzerland—report no natural capital at all.

The United Nations Statistics Division's 2023 Global Assessment of SEEA implementation[54] reports that 90 countries complied with some components of the SEEA-CF, and 35 countries complied with some components of the SEEA-EA. However, these data have not been compiled into a central database, and it is difficult to assess the coverage systematically.[55] Most countries only produce physical measurements. Only 22 countries produce monetary accounts for timber (not forest), and this is the largest share to produce monetary accounts. The next most commonly produced monetary account was for water, with only 15 countries developing a monetary account. Some countries align their SEEA data with other economic data, while others do not.

THE RIGHT PRICE: VALUATION CONCEPTS

When measuring changes in wealth it is important to consider prices and physical quantities of assets. Prices serve as the relative weights for combining different capital stocks into an aggregate wealth summary. Were markets perfect and complete, then identifying the correct prices to use, the so-called shadow prices,[56] would be easy and uncontroversial. Prices would be taken directly from observed market transactions. Since markets are neither perfect nor complete, two concerns need to be addressed to arrive at the right price for assets in CWON: the price concept and which future opportunities to count. How these concerns are addressed influences the insights one can take from the aggregate wealth summary.

It is important to distinguish between value and price. In economics, a price represents the set of things for which an incremental unit of a good can be exchanged. For example, the price for a water bottle could be the dollars[57] that are exchanged for the bottle. Hence, prices are expressed in the units dollars per quantity, where the price reflects the relative scarcity of the good—in this case bottles of water.[58] The value is defined with units *dollars per quanitity×quantity=dollars,*[59] much like an area is defined in units *meters×meters* or square meters.[60]

In the economic measurement of sustainability, there are two apparently conflicting value concepts: "exchange values" and "welfare values." The accounting context starts by assuming

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[51] There is a challenge of terminology: some asset classes that might be considered natural capital are included as produced capital, such as cultivated biological assets. Modern management of ecosystems often blurs the lines between produced and non-produced assets. For example, a forest regenerated using a shelterwood cut or a "wild" fish stock supported by aquaculture.

[52] Other countries may include natural capital on the official balance sheet. However, it is likely that the distribution of official statistics in the OECD reporting is biased in favor of greater production of these official balance sheet statistical series.

[53] None of the categories are clearly human capital, though some produced capital could potentially be considered human capital (for example, artistic originals).

[54] https://seea.un.org/content/2023-global-assessment-results.

[55] For the 90 countries with SEEA accounts and 72 countries had links to data.

[56] The term shadow price is common in economics literature but is not always used consistently. In some cases shadow price is used as the implied price of a good or service not exchanged in the market but under prevailing conditions, while other times it implies the welfare maximizing price of a good or service that is not exchanged in the market, that is, a corrective price that would lead to efficient internalization of externalities (Fenichel, Abbott, and Yun 2018).

[57] The dollar represents other consumption opportunities and is sometimes called a numeraire.

[58] Economic scarcity and physical rarity are different. Physical rarity may lead to economic scarcity, but economic scarcity is availability relative to demand. For example, mobile phones are scarce despite being ubiquitous because people are willing to forgo a substantial amount to obtain one. Venomous insects may be rare in some locales but are never scarce, as people seldom wish there were more of them.

[59] Of course, euros, renminbi, or any other currency can be used. Dollars are used here as an internationally understood shorthand.

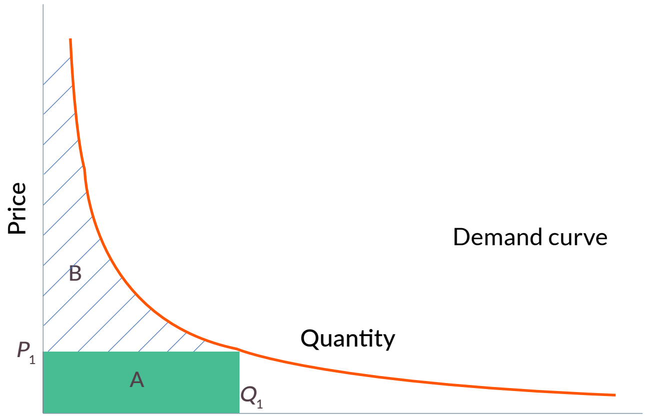
[60] Formally, price is the change in value with respect to a change in quantity, and equivalent to the marginal value. At a mathematical level, value and price are linked through the fundamental theorem of calculus: price is the derivative of value with respect to quantity, and value is the integral of price over quantity changes.

the transfer of a stock between two parties, exchanged at a specific (market) price.[61] However, what is often observed is only sale value and quantity, so that the price needs to be imputed by dividing the sales value by quantity.[62] When a price and quantity measure are available, then the "exchange value" can be computed by multiplying the price at the prevailing quantity by that prevailing quantity, as illustrated in Figure 1.2, yielding area *A* for price $P_1$and quantity Q_1. To understand what is meant by the term "welfare value" on the other hand, it is important to recognize that welfare measures always refer to a difference between two possible conditions, that is, a change from liquidating quantity Q_1. Thus, to measure the "welfare value" associated with quantity Q_1, the change from quantity Q_1 to zero needs to be considered, which is defined by the area *A*+*B* in Figure 1.2.

These value concepts imply different values of holding quantity level Q_1. On the one hand, a national accountant would observe quantity Q_1, which is the units of a good that is produced or held in capital (and whose service is fully within the production boundary) as well as the observed market price P_1. The area measure *A* would thus represent the observed market-based transaction value or *exchange value*.[63] The welfare economist, on the other hand, would consider the *welfare value* of the provision of the good Q_1 relative to a counterfactual, here shown as no good at all, that is, relative to zero quantity. This is represented by the area under the marginal value curve (generally the demand curve), which is area *A*+*B*.[64] This is clearly different from the exchange value recorded by the accountant, who is not interested in the hypothetical counterfactual. While the national accountant and welfare economist disagree on the value, they can agree on the observed price and quantity—assuming there is first agreement on the accounting boundaries.

FIGURE 1.2

Exchange value vs. welfare value



It is important to understand to what extent these different perspectives can be reconciled, because CWON aims to align itself (where possible) with SNA and SEEA standards and guidelines for measurement, while also looking at sustainability, which is associated with changes in welfare (Arrow et al. 2004). The convention in the SNA is to use exchange values. Where possible, valuation is based on observed market prices,[65] though the SNA imputes some prices when necessary. The SNA acknowledges that it operates in a world with market failures, which means that the measured price vector may not maximize social welfare. By applying the SNA concept of exchange value, the real CWON wealth measures (in levels) will thus reflect values based on the policy environment and market structure, including any market failures, but not first-best "welfare values."[66] Nonetheless, prices measured from actual market transactions generally align with the second-best welfare concept (Lipsey and Lancaster 1956), enabling change-in-welfare interpretations.

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[61] In fact, the SNA guidance defines exchange value like a market price, with paragraph 3.121 stating that "exchange values in most cases will represent market prices." However, the term "exchange value" should be, and commonly is, used in the "area" sense to refer to measures consistent with the SNA framework. This point is being clarified further as part of the 2025 SNA revision process.

[62] This imposes an assumption of a constant marginal price.

[63] This assumes that all the quantity can be traded without affecting price.

[64] One common approximate welfare measure is the change in the sum of producer and consumer surplus, which is the area under a demand curve less the costs of provision. In the case of gross measurement, cost of provision is not subtracted. In that case, only the area under the demand curve matters. Welfare economists recognize that consumer surplus, as defined by the Marshallian demand curve, is not the appropriate measure for non-marginal changes and prefer Hick's compensated surplus measures for welfare analysis (Freeman 2003).

[65] It is important to note that for CWON measures of capital prices, it is the prices themselves that are forward-looking and are best thought of as the price of net changes in capital. This means that expenditure-based methods, like those used for public services such as health care, education, public transportation, and public parks and conservation areas are unlikely to align with the marginal real income contribution. There are many reasons this can be the case. First, discount rates used to analyze government expenditures may differ from the social discount rate. Second, seldom do decision analyses account for general equilibrium effects. Third, some public services like parks and schools are established on natural and human capital that are not generated through markets.

[66] This is true even if the prices are second-best welfare consistent.

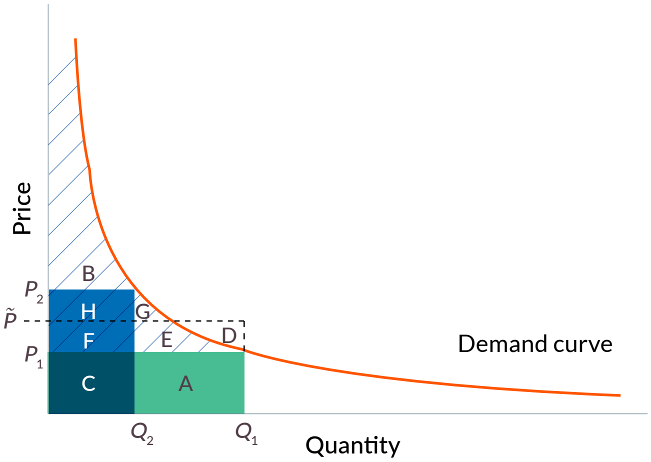
However, to analyze the sustainability of progress, one must analyze how real wealth changes over time, that is, how wealth changes after removing general price (substitution) effects. Changes in real wealth need to account for changes in quantity between the two accounting periods and changes in prices, because fluctuating prices reflect changes in substitution patterns. These patterns are part of the behavioral responses that are important for sustainability. This is like the challenge of measuring changes in real (or volumetric) GDP (or NDP). Prices for stocks of capital change as a result of changes in scarcity of the stocks being measured or because of changes in potential substitutes or complements. Prices can also fluctuate because of institutional or policy changes. Yet, the goal of measuring changes in wealth is to ask how much more aggregate consumption can happen, which means accounting for substitution patterns and not misidentifying them as wealth effects.

The main question is what price to use. Consider the change from good level Q_1 and price P_1 to good level Q_2 and P_2, as illustrated in Figure 1.3. The welfare economist would compute the difference in welfare values, which would yield a change in welfare equal to area *A+E+G*. An accountant, on the other hand, might compute the difference in nominal exchange values yielding area *F+H-A*. However, this is not a meaningful real value measure in either the SNA or welfare context. A reasonable and intuitive approach for calculating differences in exchange values is to average prices, $\tilde{P}$,[67] instead such that the change in wealth would be calculated as $\tilde{P} \times (Q_1 - Q_2)$ equal to area *A+E+D*. If the marginal price curve were a straight line, then *G=D*, and this provides a good approximation of the size of the change if the demand curve can be reasonably approximated with a straight line.[68] In this case, the welfare economist and accountant would agree on the change in value. However, a simple average price is only able to account for changes in price due to the changes in the demand for stock holding the demand curve constant, for example, as the amount of the good is reduced from level Q_1 to level Q_1. The approach of finding an average price is not a good approximation if consumers substitute this good for another, leading to shifts in the demand curve itself. In that case it would be necessary to account for some of the curvature properties.

Furthermore, price curves often have the curved shape shown in Figure 1.2 or Figure 1.3, which can lead to errors when computing the area under the demand curve between the opening and closing quantity.[69] In such a situation, Diewert (1992) shows that the Fisher ideal index, a so-called "superlative index,"[70] provides a good approximation.

FIGURE 1.3

Changes in prices and their implications for exchange and welfare values



Note: The area shaded in green (C+A) represents the exchange value of quantity Q_1. The area shaded in blue (C+F+H) represents the exchange value of quantity Q_2.

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[67] In academic studies of the change in wealth, typically an average price or arithmetic mean is chosen. See, for example, Arrow et al. (2012), Dasgupta (2014), and Yun et al. (2017). The average price approach is equivalent to averaging a Laspeyres and Paasche index.

[68] This result follows from standard Euclidean geometry. It is also the case that the smaller the change in Q, then the more likely a straight line is to be a good approximation of the demand curve over the change being considered.

[69] To compute changes in wealth one must compute the area under the demand curve between the opening and closing quantity. This follows directly from the fundamental theorem of calculus and the definition of an asset price as the marginal value of an asset (Jorgenson 1963).

[70] A superlative index is any price or quantity index that can provide a second order approximation to a welfare change. The Fisher ideal index for a single good is defined as a geometric mean of prices, which is computed as √(P_1^2 P_2^2), while the arithmetic means are computed as 1/2(P_1+P_2). More generally, the Fisher ideal index is the geometric mean of the Laspeyres and Paasche indexes.

Furthermore, Diewert shows that superlative indexes are capable of reflecting changes in substitution to isolate the income effects. An equivalent way to approximate area $A+E+G$ can be achieved by applying the Törnqvist index. The Törnqvist index is also a superlative index, which provides the same result as the Fisher ideal index (up to a small approximation error) even when there are multiple stocks (Dumagan 2002), but is computationally simpler to implement. The Fisher ideal and Törnqvist indexes are regularly used in national accounts to compute real GDP. This edition of CWON uses a Törnqvist volume index to compute changes in real wealth (for more detail refer to chapter 2).

Real changes in CWON's comprehensive wealth estimates measured using the Törnqvist volume index could thus approximate real changes in welfare, if the capital stocks included were truly comprehensive.[72] This is because the shape and location of the marginal value (price) curve depend on the accounting boundary. To illustrate this point, consider a forest. The SNA production boundary includes timber and fuel wood production but excludes some non-wood ecosystem services that are part of the future production opportunities considered in CWON. Therefore, a national accountant adhering strictly to the SNA production boundary would arrive at a different marginal value curve for standing forests than an analyst using the services enumerated in CWON, which also include the forest's role in water provision.[73]

Although the CWON program has pushed the measurement of wealth beyond the current SNA accounting boundaries to account for services believed to be important for sustainable development, its coverage is still not comprehensive. Nevertheless, the CWON balance sheet remains one of the most comprehensive measures of non-financial assets available today. The question thus becomes whether the approximation is "good enough" for a second-best world, where the observed market prices reflect inefficient economies and missing markets and where the services from those missing assets can distort market prices through complementarity and substitution effects. The answer is that it is likely better than current alternatives and hopefully gives the correct sign of the change. Nonetheless, these changes in wealth should not be interpreted as changes in welfare.

WHAT CWON MEASURES: THE ASSET BOUNDARY

The CWON program aims to fill some of the data gaps identified above by producing estimates of changes in real comprehensive wealth per capita for 151 countries for the 1995 to 2020 period. These measurements are intended to be comparable across countries and over time, and cover five asset classes: produced capital, nonrenewable natural capital (fossil fuels and metals and minerals), renewable natural capital (agricultural land, forests, mangroves, marine fish stocks, and renewable energy), human capital, and net foreign assets.

While the CWON methodology aims to align where possible with internationally accepted statistical standards and guidelines of the SNA and SEEA, the grouping of assets in CWON differs from the SNA (see Figure 1.4). The SNA first divides assets into financial and non-financial (real) assets, while CWON is mostly focused on non-financial assets. Within the category of non-financial assets, the SNA divides them further into produced and non-produced assets. Some "natural capital," such as plantation forests and aquaculture fish stocks, are also included as cultivated biological assets within the produced asset section, while they are grouped under renewable natural capital for CWON. On the other hand, the SNA treats all land as a non-produced asset, while urban land is included under produced capital for the purposes of the CWON database.[74]

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71 The single good case is used to develop intuition. In the applied multi-good setting, the relative importance of a price is weighted by the quantities to which it is attached to create a "volume" measure. This is effectively an approach to approximating the multidimensional integration problem.

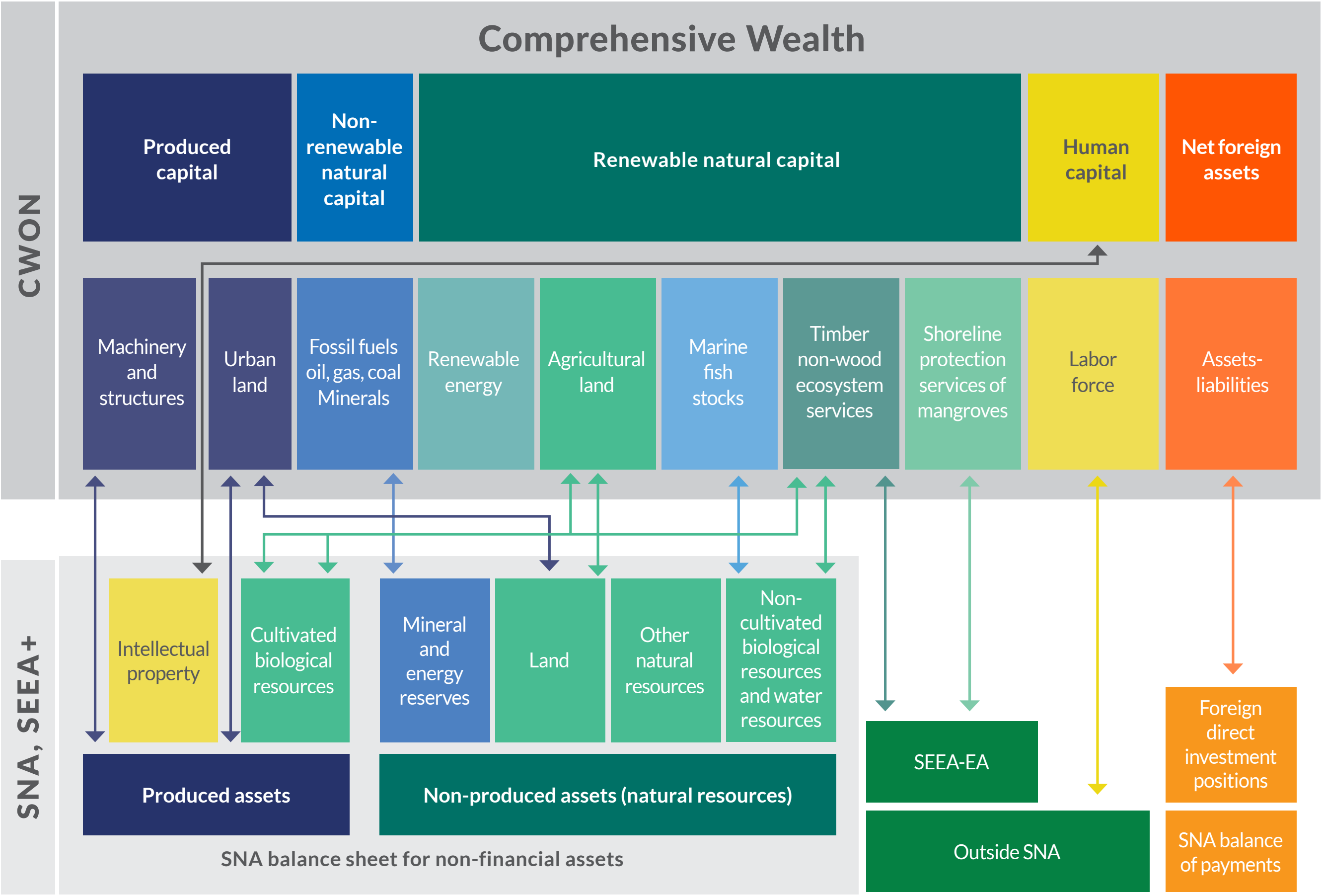
[72] This also means that the services included in the associated income measures were also comprehensive—this depends on the accounting boundaries. This is likely not the case for CWON, but CWON continues to expand beyond the current SNA production boundary.

[73] Hashida and Fenichel (2022) address this challenge by examining actual decisions landowners make about harvesting trees from a forest. They find that on the fastest-growing sites the revealed value aligns very closely with what one would expect from institutions that only considered timber. However, on slower growth sites the decision-makers acted as if there were added value to standing forests beyond their timber value. The revealed value thus also included services provided by their forests outside of the SNA and possibly within the SEEA-EA production boundary.

[74] This choice is primarily driven by the methodology used, as urban land is estimated as a share of produced capital, drawing on Kunte et al. (1998).

FIGURE 1.4

The CWON wealth accounts (2024 release) and their relationship to the SNA and SEEA



Note: Arrows represent where components of CWON can be found in the SNA system, including the non-financial asset balance sheet and balance of payments accounts or in the SEEA-EA (the SEEA-CF is fully aligned with the SNA).

Most of the assets covered in CWON, such as machinery and structures, fossil fuels, metals and minerals, urban and agricultural land, timber, and marine fish stocks, are all clearly within the asset boundaries of the SNA and SEEA-CF, which is fully aligned with the SNA, and are part of the SNA balance sheet of non-financial assets. Renewable energy assets are not yet part of the SNA. However, guidelines for their inclusion, which were developed for the previous CWON report, were endorsed as part of the 2025 SNA revision process.[75]

Changes in this subset of SNA assets do not sufficiently embody the changes nations face with respect to future production (and ultimately consumption) opportunities, requiring CWON to go beyond the SNA and SEEA-CF asset boundary. In fact, over time CWON has expanded the asset boundary to include key SEEA ecosystem accounts, which includes allowing non-timber forest ecosystem services (some of which may be in the SNA, such as non-wood forest products like mushroom harvesting, while others, such as recreation, are not) into forests. It also includes important regulating services such as shoreline protection services capitalizing into mangroves (which may be partially attributed to property value in the SNA). And, with this update, experimental estimates of climate regulation provided by terrestrial ecosystems are included (which might be partly captured by the SNA to the extent that asset prices account for climate risks, but its non-market benefits are clearly not captured in the SNA).

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[75] https://unstats.un.org/unsd/nationalaccount/aeg/2022/M21/M21_14_WS11_Renewable_Energy_Resources.pdf.

CWON also includes other assets critical for sustainable development, notably human capital. The SNA does not provide the same entry points for human capital as it does for natural capital. It includes intellectual property, such as software and artistic originals, as produced capital. In addition, some statistical offices have produced satellite accounts that address elements of human capital, and there is international cooperation in this area (United Nations Economic Commission for Europe 2016). Guidelines on how the dimensions of education, human capital, and labor could be included within the SNA were developed and endorsed as part of the ongoing 2025 SNA revision process.[76] Still, systematic measurement of human capital remains an even larger gap than that for natural capital, which CWON steps in to help close.

The key limiting factor in expanding the asset coverage further is data availability. To ensure comparability across countries and over time, data are primarily sourced from global databases. However, these data usually have limited assets, country, and temporal coverage—and often lack the necessary granularity. For example, aquaculture has become an important industry that now matches marine capture fisheries in terms of production volume and value (FAO 2022). Given this, aquaculture-related ecosystem assets should be included in the CWON database, as they, in combination with other inputs, contribute to benefits enjoyed by humans.[77] Yet a comprehensive assessment of the wealth arising from aquaculture is not possible today due to data limitations. A first step in that direction was taken with this edition of CWON by compiling pilot accounts for a subset of species and countries (for more detail see chapter 8). A back-of-the-envelope calculation based on this pilot suggests that aquaculture-related natural capital may be four times more valuable than that of marine fish stocks.

For some assets there is limited international guidance and implementation experience, especially in the context of wealth accounting. The development of valuation guidelines for ecosystem services is ongoing, and several key questions remain unresolved. One such example is carbon retention services provided by terrestrial ecosystems, such as forests or mangroves, which play a key role in climate mitigation efforts. While it is possible to produce experimental estimates at the global scale (as done in chapter 7), there is no agreed approach on how to attribute these estimates at the country level due to its global public good nature. Nor is there unanimity on how to avoid double-counting when aggregating the value of carbon retention with other assets.[78] Similar conceptual concerns arise when accounting for critical assets such as water,[79] which are further compounded by data and modelling constraints (see Box 1.2). For these reasons, several important assets cannot yet be included in CWON's comprehensive wealth estimates, but there might be future opportunities as data availability improves and remaining conceptual issues are resolved.

WHAT CWON IS MEASURING: THE VALUATION APPROACH AND AGGREGATE WEALTH MEASURES

The approaches and concepts used by CWON to value assets align where possible with SNA and SEEA statistical standards and guidelines and use the national accounting "exchange value" concept. The valuation approaches used vary across asset category (for more detail, see chapter 2). For example, for the calculation of physical capital stocks, CWON follows the SNA guidance and international practice in employing the perpetual inventory method (which assesses value as equivalent to depreciated past investment rather than expected net present value of the flow of services). The valuation

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[76] https://unstats.un.org/unsd/nationalaccount/RAdocs/ENDORSED_WS4_Labour_Human_Capital_Education.pdf.

[77] These assets include the equipment and installations (pens, ponds, and so on) used to farm fish (produced capital), the breeding stock and inventories of partially grown fish (also produced capital), and the ecosystem inputs to fish farming (natural capital). The value of the produced capital data used in aquaculture is, in principle, already captured in the produced capital values CWON draws from the Penn World Tables (PWT), so it may not need to be added. The value of the natural capital used in aquaculture, on the other hand, is missing from CWON, and methods and data would have to be found to value it if it were to be added. This would require data on prices and production quantities, which are publicly available, and on costs, which are unfortunately rarely collected systematically.

[78] It is reasonable to assume that the benefits of carbon retention are at least to some extent already captured in the prices of other assets currently included in CWON. To avoid double-counting, only non-market benefits should be included.

[79] The value of water is already partly accounted for in agricultural land and hydropower, but it is difficult to account for that contribution.

approach for nonrenewable and renewable natural capital assets is based on the residual value method (RVM) or net present value (NPV) approach recommended by the SNA and SEEA-CF, while ecosystem assets are valued separately using approaches recommended by the SEEA-EA. For the valuation of human capital, CWON uses the lifetime earnings approach developed by Jorgenson and Fraumeni (1989, 1992a, 1992b), which is one of the statistical approaches recommended by the ongoing 2025 SNA revision process.[80]

The main methodological innovation introduced with the current update of the CWON database is the use of the Törnqvist volume index to compute changes in real wealth (for more detail, see chapter 2).[81] In this approach, the relative changes in the physical assets of a nation, such as the size of its fish stocks or the number of workers in the labor force, are weighted by their relative economic importance (as measured by their shares in nominal wealth). Changes in real wealth per capita will be driven by (i) the depletion or accumulation of assets (through relative changes in physical assets), (ii) changes in the productivity, or relative scarcity, of assets (through relative price changes), (iii) changing substitution patterns (through cross-price and quantity effects), and (iv) increasing or decreasing competition for available assets (through demographic pressures); all of which are important for analyzing the sustainability of economic progress. Moreover, the use of the Törnqvist volume index bridges the notions of change in real exchange value and change in welfare value, making this debate more about what is in the accounting boundary than the value concept itself.

Past editions of CWON calculated wealth changes in constant prices using the GDP deflator, which was convenient to mainstream wealth accounting, but this edition aligns the deflation approach with best practice. One key concern when using the GDP deflator is that (just like GDP) it only covers current flows of domestic production (not consumption) within a given country and excludes all imported goods or services. Take the example of a country whose production is heavily weighted toward oil, such as Nigeria or Saudi Arabia. In such cases, the GDP deflator will be driven by the price of oil, but will not reflect the price of the goods that are consumed in that country, such as vehicles, machinery, or cell phones—many of which are imported. If the goal is to understand the evolution of the real purchasing power of a nation's wealth, a domestic demand deflator should be used instead. Even when applying other price-based deflators, changes in real wealth will be distorted by short-term price volatilities, which are removed when using a volume-based index. Third, given many countries compute real GDP with the price weights of a fixed base period, resulting GDP implicit price deflators[82] would not account for substitution. However, accounting for changes in substitution patterns, as the Törnqvist volume index enables, is fundamental to the analysis of sustainability, as substitution opportunities will change over time with changes in the relative scarcity of assets.

CONCLUSIONS

GDP is widely recognized to be an insufficient measure of progress and national "success." Whether progress is sustainable can be measured by how real wealth per capita is changing, as this represents changes in future production (and, ultimately, consumption) opportunities. However, while almost all countries produce and use GDP, only a few countries produce wealth measures, particularly wealth measures that are comprehensive and include natural and human capital. The CWON database aims to fill this data gap by producing comparable and consistent comprehensive wealth estimates for 151 countries for the last quarter of a century.

While CWON aspires to measure wealth comprehensively, its coverage is still limited by methodological and data constraints. The CWON measurement has gradually expanded with each edition, as new data and statistical standards have become available. The current coverage includes key assets from the SNA balance sheet and several critical ecosystem

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[80] The endorsed valuation guidance for the SNA 2025 revision process can be found here: https://unstats.un.org/unsd/nationalaccount/RADOCS/ENDORSED_AI1_Valuation_Principles_Methodologies.pdf.

[81] This edition also introduces several other innovations and improvements in methodology to enhance both internal consistency and alignment with the SNA and SEEA standards, and existing as well as emerging guidelines. These changes are discussed in detail in chapter 2 as well as in the dedicated asset-specific chapters.

[82] The estimation of real GDP is typically done at a very detailed level. There is thus not one "deflator" used in its derivation. Instead, the overall price change for the products encompassed in GDP (that is, domestically produced goods and services) is derived implicitly by the ratio of nominal to real GDP.

assets that generate ecosystem services that are covered by the SEEA-EA. CWON goes beyond the current SNA standards to include human capital. However, the measurement of wealth is still not comprehensive, as key natural capital assets, such as water, aquaculture, and climate regulation services cannot be included due to theoretical and practical concerns. Therefore, changes in real wealth per capita cannot yet be used to make inferences about changes in welfare, but they can be used to track economic progress.

By tracking changes in real comprehensive wealth per capita over time, policy makers can assess the sustainability of a nation's progress. As long as real wealth per capita is not declining, economic progress may be sustainable. Of course, a nation may choose in the short term to draw down some of its wealth to support current consumption over and above the level that current production would allow—say, during a temporary downturn. However, no nation can allow its real per capita wealth to continually decline without welfare eventually also declining due to reduced production possibilities. Such information is critical for development planning. For example, it can help direct investment toward assets that need to be accumulated faster, so they can keep up with population growth or identify assets that are being degraded and require more sustainable management.

Wealth data can also help inform asset diversification strategies, as countries aim to alleviate the constraints imposed by the physical extent of assets by shifting the allocation of their overall wealth portfolios. This has, in fact, been a key element in the development of many nations. Natural capital endowments are often drawn down to provide income to fund investments in other assets with greater marginal value. When done carefully and with a clear understanding of the limits to which natural capital can be drawn down, this can be an effective means of increasing welfare. This is a point taken up further in this report in the discussion of weak versus strong sustainability (see chapter 4).

BOX 1.2

ACCOUNTING FOR WATER IN CWON—CHALLENGES AND OPPORTUNITIES

Water is a vital resource for all countries, but water valuation is challenging for theoretical and practical reasons. These include the physical characteristics of water, the way water is regulated and used within the economy, and the fact that water is an essential good. For these reasons, water valuation is contentious and the observed water prices are seldom a true reflection of the marginal value of water.

As part of the ongoing development of CWON, three approaches to water valuation consistent with the valuation concepts and methods of the other assets included in CWON and the SEEA were identified by Vardon et al. (2024): asset-by-asset, use-by-use, and ecosystem service-by-service.

- ***Asset-by-asset:*** This bottom-up approach is based on observed market transactions of water assets within countries. This is problematic because the direct trade of water assets rarely occurs. However, while the water assets themselves are not traded, their value can be determined through the value of trades in water rights, which are a "permit to use a natural resource" and are a financial asset in the SNA (see paragraphs 17.324 and 3.36, respectively). However, while some countries and regions have tradable water rights—for example, Australia, Chile, Iran, South Africa, and parts of the United States (UN 2021)—most countries do not. Concerns have also been raised about the functioning of some water markets (for example, Garrick et al. 2020). Still, Fenichel et al. (2016) shows how an asset-by-asset approach can be used for water when high-quality data are available.

- ***Use-by-use:*** This is another bottom-up method, which uses country-by-country assessments of water use by different industries, such as agriculture, mining, manufacturing, energy, water supply, education, health, and so on. In this, the value of water used is embedded in the value added by each industry, rather than just the price paid per unit volume used. The SEEA water supply and use tables could provide the information necessary to implement this approach, but these are only available for a handful of countries at the level of detail needed.

- ***Ecosystem service-by-service:*** This approach could use either a bottom-up or top-down method. Bottom-up would require country-level ecosystem service accounts, but as very few countries have these accounts, this method is not possible. A top-down method could be used, building on the approach developed to estimate the value of forest ecosystem services in CWON (Siikamäki et al. 2024). In this method, the value of forests is derived from a meta-analysis of the existing academic literature on ecosystem services, including erosion control, flood protection, hydropower, and water services. It is a service-by-service approach that can be extended to cover all ecosystem types (beyond forests) and value water assets.

Each approach to water valuation has its advantages and drawbacks, with the service-by-service approach being the most feasible in the short term. The growing uptake of water and ecosystem accounting by nations using the SEEA, combined with new data sources and tools for account production, will make all approaches more feasible in the long term. Confounding the difficulties of water valuation is that the value of water is already embedded in the value of other assets included or intended to be included in CWON. This includes agricultural and forested land (Siikamäki et al. 2024) and renewable energy (Smith et al. 2024). If a separate valuation of water is included in CWON, then it could be presented as a standalone value, independent of asset values, or deducted from the value of other assets.

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2 How the World Bank Measures Comprehensive Wealth

MAIN MESSAGES

- CWON wealth estimates align where possible with the internationally accepted statistical standards and guidelines of the System of National Accounts and the System of Environmental-Economic Accounting. CWON goes beyond these standards to include additional assets critical for sustainable development, such as human capital and key ecosystem assets.
- This edition of CWON implements an important methodological innovation that affects how real wealth per capita and its changes over time are measured. Real wealth estimates are computed using a chained Törnqvist volume index, where the physical assets of a nation, such as the size of its fish stocks or the number of workers in the labor force, are weighted by their economic importance.
- Changes in real comprehensive wealth per capita will be driven by the depletion or accumulation of assets, changes in the productivity or relative scarcity of assets, changing substitution patterns, and increasing or decreasing competition for available assets. All of these are important for analyzing the sustainability of economic progress.
- Future efforts should build on the critical methodological innovations introduced with this edition, and improve the implementation of the volume index, especially the measurement of physical volumes.

INTRODUCTION

The World Bank's The Changing Wealth of Nations (CWON) program is a pioneering effort in the measurement of wealth, producing a regularly updated global database of comprehensive wealth estimates for nearly two decades. These estimates are aligned where possible with the United Nations' System of National Accounts (SNA; EC et al. 2009), the System of Environmental-Economic Accounting Central Framework (SEEA-CF; UN et al. 2014), and the System of Environmental-Economic Accounting Ecosystem Accounting (SEEA-EA; UN et al. 2021) to ensure comparability with other widely used statistical measures, such as GDP. With each new CWON edition, the measurement of wealth has been updated and expanded as new data sources, methods, statistical standards, and guidelines have become available.

This edition of CWON implements an important methodological innovation that affects how real wealth per capita and its changes over time are measured. CWON 2024 computes real wealth using a chained Törnqvist volume index in line with SNA guidance for computing capital stock estimates adjusted for general price effects (SNA, paragraphs 15.167–15.172). These are commonly referred to as "real"[83] asset values—a term used in this report.[84] What this means is that changes in real wealth per capita will now track how the real asset base of a nation and relative prices change over time. Real wealth per capita will increase if capital is accumulated, as, for example, more workers enter the labor force, forests are replanted, or hydropower plants are connected to the grid. It will decline if wealth is depleted too rapidly, as is the case when fish stocks are overfished or the reserves of fossil fuels are depleted, and the resulting

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[83] As noted further below (see footnote 88), our use of the term "real" here is not, strictly speaking, aligned with guidance on the compilation of stock measures in the SNA. It is, however, consistent with general practice in the presentation of inflation-adjusted data by statistical agencies.

[84] The transition to a volume-based index was recommended as part of a wider methodological review led by Robert Smith (Midsummer Analytics) and supported by a technical advisory committee comprising Matthew Agarwala (Bennett Institute for Public Policy, University of Cambridge, and Tobin Centre for Economic Policy, Yale University); Catherine Van Rompaey (World Bank), Karen Wilson (former assistant deputy head of Statistics Canada), and Rintaro Yamaguchi (Japanese National Institute for Environmental Studies). Similar recommendations were also made as part of a review of deflation methods for CWON wealth measures (Inklaar et al. 2023). The change will ensure consistency in deflation methods across asset types, as real produced capital estimates from the Penn World Tables, used in the CWON database, are also computed as a volume-based index (Penn World Table 10.01 by Feenstra et al. 2015).

rents are not reinvested in other assets. The weight these changes are given in the comprehensive wealth index is determined by their nominal value (measured as a share of total value in current US dollars at market exchange rates) and changes in relative prices over time, which are driven by changes in scarcity of the stocks being measured, changes in the availability of potential substitutes or complements, or institutional and policy changes.

The remainder of this chapter proceeds as follows. First, a discussion is presented on how a real measure of aggregate comprehensive wealth can be computed and why a chained Törnqvist volume index was adopted for this edition. The chapter then explains which assets are included in CWON. Next, the chapter discusses the broad valuation approach, and which common assumptions are applied to all valuation approaches (where applicable) to ensure consistency of methods and comparability of value estimates across assets. It then describes briefly how each asset in CWON is valued and the extent to which the valuation approaches align with SNA and SEEA standards and guidelines. It concludes with a summary of the outstanding conceptual, methodological, and measurement challenges that future CWON editions should tackle.

A NEW APPROACH FOR COMPUTING REAL COMPREHENSIVE WEALTH

Even though the final goal is to estimate changes in real comprehensive wealth per capita over time, the level of aggregate comprehensive wealth—that is, the value of all the assets in a nation's comprehensive wealth portfolio—must be computed first. Aggregate comprehensive wealth is compiled in nominal and real terms in CWON. Compilation in nominal terms is straightforward. Nominal aggregate comprehensive wealth is simply the sum of each of the assets measured in nominal terms themselves, using market exchange rates. Measuring aggregate real wealth, such that only relative price changes are accounted for, is more complicated. Doing so requires a decision on how to remove all other price effects.

In the past, CWON's approach was to compile aggregate real comprehensive wealth by deflating the nominal value of each asset using a GDP deflator and then adding the deflated asset values together. Implicit in this approach was the view that consumption possibilities must be maintained to ensure the sustainability of well-being. This approach had the advantage of familiarity and tractability, with GDP deflators being readily available for most countries from national accounts data. However, it also had two main shortcomings (Sefton and Weale 2006; Inklaar et al. 2023; see annex A1):

1. ***Wealth as a measure of future production opportunities:*** Deflation using the GDP deflator (or any price deflator for that matter) implicitly treats all assets in the comprehensive wealth portfolio as fungible—or interchangeable—stores of value, readily converted to money to be spent on goods and services. While this aligns with the work of many leading theoreticians of wealth accounting (Arrow et al. 2004; Dasgupta 2001), it is not well aligned with the view of sustainability taken in previous CWON reports: "A nation's income is generated by its [comprehensive] wealth" (CWON 2021, 25). This view places the emphasis squarely on the sustainability of production (since production is the source of income), which will subsequently ensure the sustainability of consumption. The goal is to measure changes in the real productive base of the economy, and thus, a comprehensive set of productive assets, such as machinery, forests, and people.
2. ***Appropriate deflator for the real purchasing power of national wealth:*** Even if CWON were to use a price deflator, which is troublesome as price-based deflators introduce confounding price effects and cannot isolate substitution effects, the GDP deflator is not the most appropriate choice. One key concern when using the GDP deflator is that (just like GDP) it only covers current flows of domestic production (not consumption) within a given country and excludes all imported goods or services. For example, a country with an economy dependent on fossil fuel production for export will experience quite different price trends in its production activities than in its consumption activities. The former will be dominated by international prices of bulk oil, gas, and coal, while the latter will be dominated by the prices of consumer goods and services, many of which will be imported. For any open economy, deflation of national wealth using the GDP deflator will not result in a meaningful measure, whether in terms of a total volume of wealth assets or of a constant purchasing power.

Given these shortcomings, CWON 2024 has shifted away from the GDP deflator in favor of an approach focused on assets as inputs to production processes. This approach rests on constructing an index in which the quantities—or "volumes"—of the various assets comprising comprehensive wealth are aggregated together using their nominal values as weights. A "volume" in this context refers to a physical quantity of a given asset, which can be measured in different units. For example, the volume of agricultural land is measured in hectares, while the volume of oil assets is measured in barrels. The volume index can sum across assets measured using different units by weighing changes in volumes over time by their time-varying shares in nominal wealth. Volume changes related to assets that make up a greater share of nominal wealth, such as human capital, are thus given a greater weight in the index. Such a volume index aligns with the idea that what matters for sustainability is not preserving assets as stores of value but, rather, preserving them as entities that, when combined with one another in production processes, yield the goods and services that are themselves the object of consumption.

In this context, wealth is best thought of, and measured, in the most concrete terms possible. This is what is demanded when actual forests, mineral deposits, machinery, and the people that make up the workforce are all seen as part of national wealth. Take human capital as an example. The knowledge, skills, and capacities of workers cannot be bundled together and sold off to the highest bidder. These characteristics and qualities are inherent to the individuals who possess them. The value of human capital can thus only be realized when workers choose to offer (or rent) it to others temporarily in return for wages as part of an employment arrangement, or, alternatively, to use it themselves in carrying out their own production activities. Similarly, much natural capital—especially ecosystem assets that are not bought and sold in the market—has value as an input into a production process.[85] Countries cannot dig up ecosystems and sell them to their neighbors. An exception is made for financial assets, which are relatively liquid and can be converted to cash in the short term. Financial assets can thus be logically deflated with the CPI.[86]

The choice to move to a volume index for CWON 2024 meant that a specific index had to be chosen from among the many possibilities (World Bank et al. 2004); a decision that was guided by international best practice. A commonly used index is the Fisher ideal index,[87] which many national statistical offices use to express changes in price or volume. Advanced economies like Canada and the United States use the Fisher ideal index to estimate GDP in real terms. As discussed in chapter 1, this index also has many desirable theoretical properties (Diewert 1976), most notably its ability to capture relative price and volume changes, and to account for substitution effects. It has drawbacks in practice, however. Notably, a complex formula is required to derive the contribution of each element of the index to the overall growth in the index (Chevalier 2003). An index that avoids this and shares many of the same theoretical qualities is the Törnqvist index (Törnqvist 1936; Dumagan 2002).

HOW REAL COMPREHENSIVE WEALTH IS COMPUTED

CWON 2024 has adopted the Törnqvist index to compile "real" comprehensive wealth estimates,[88] measured as the price-weighted volumes of assets and expressed in monetary terms using "chained" prices. The year 2019 was chosen to compute the real asset values. The choice of reference year is ultimately arbitrary, but 2019 was chosen for CWON 2024 because it is the most recent year in the database that was not

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[85] In this context, "production" includes the production of non-market goods and services like flood control and recreational opportunities.

[86] CPI was chosen over the GDP deflator in CWON 2024, given the concern noted above about the appropriateness of the GDP deflator in the context of wealth accounting.

[87] Fisher himself referred to it as the "ideal index," but it has come to be so associated with him that it now bears his name.

[88] The primary objective of any measurement in "real" terms is separating price and volume effects. By removing the general price (inflation/deflation) effect, the real measure will only capture the volume and relative price effect. "Real" values (sometimes referred to as "constant price" values) are, strictly speaking, values that have had the general price removed from them by the application of a price index to their nominal value (see SNA para 2.66). Values that have had the general price effect removed from them by direct consideration of quantities are properly referred to as "volumes." However, it is common practice in statistics to use the term "real" even when "volumes" are referred to, likely because the term is broadly understood to mean "after removing the influence of changes in the general price level." Thus, CWON 2024 retains use of the term "real" even though, strictly speaking, it is asset "volumes" rather than "real asset values" that are presented.

a crisis year (2020, the latest year in the database, was marked by the beginning of the COVID-19 pandemic). A range of chained Törnqvist volume indexes are then compiled for the CWON database, including indexes for all individual assets (for example, timber or agricultural land), for each individual asset class (for example, renewable natural capital), as well as for aggregate comprehensive wealth (which comprises produced capital, nonrenewable and renewable natural capital, human capital, and net foreign assets). Readers interested in additional details are referred to annex A2 of this chapter and to the overall methodology report (World Bank 2024).

While choosing an index that emphasizes changes in the volume of assets is a major improvement, it is important to note that in doing so the impact of prices on the value of assets and, ultimately, changes in wealth is not lost. As volume changes are weighted by nominal shares for adjacent periods, changes in relative prices are accounted for.[89] Real wealth per capita will thus increase if capital is accumulated—for example, when more workers enter the labor force, or if the productivity[90] of a given asset increases when the same workers upgrade their skills. However, it will decline if assets are depleted and becoming harder to substitute. For example, as fish stocks are being depleted, initially more fishing boats might be able to sustain a given harvest level. But, as overfishing continues, more fishing boats will not be able to offset the declines in fish stocks. Real wealth per capita will also decrease if the population grows faster than wealth is accumulated, as there is more competition for a given set of assets.

Changes in real comprehensive wealth per capita will directly capture key effects that are important for analyzing the sustainability of economic progress, namely:

- The depletion or accumulation of assets (through relative changes in physical assets).
- Changes in the productivity or relative scarcity of assets (through relative price changes).
- Changing substitution patterns both across and within asset classes (through cross price and quantity effects).
- Increasing or decreasing competition for available assets (through demographic pressures).

It is important to note that, in practice, the current method does not fully reflect changes in the quality of assets over time, as it ideally should. For example, if the agricultural land available in a country declines over time by area due to desertification, and in its productivity due to a loss of nutrients in the soil, both changes should be captured in the index. However, only the former is reflected in the index due to data constraints (for more detail see annex A1). The current approach can capture increases in productivity, which in the case of agricultural land would be reflected in higher nominal asset values of the inputs to agricultural production, namely produced and human capital. In other words, higher yields due to better tractors or climate-smarter farmers would be reflected in higher average and marginal revenue product of produced and human capital, respectively. Improving the "quality" measurement of the physical volumes should be a priority in future extensions of this work.

ASSETS INCLUDED IN CWON

The CWON program aspires to measure wealth comprehensively across five asset classes: produced capital, nonrenewable natural capital, renewable natural capital, human capital, and net foreign assets (see Figure 1.2). In practice, this aspiration cannot be fully realized, as data constraints limit the coverage of the assets that can be valued, especially for renewable natural capital, as discussed in chapter 1. The current update of the CWON database covers 151 countries—adding Angola, Guinea-Bissau, Israel, Montenegro (after 2007), New Zealand, São Tomé and Príncipe, Serbia (after 2007), St. Lucia, and Sudan (after 2011)[91]—for the 1995–2020 period and includes the following assets (assets marked with an asterisk are new in this edition):

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[89] This is the case for comprehensive wealth measures as well as the real value of selected asset classes. However, the real value of an individual asset will only be driven by changes in volumes (not prices).

[90] Productivity is defined here as the output per unit of (labor and capital) input, and can increase due to a broad variety of factors, such as good management practices, more efficient production processes, and improved quality of intermediate inputs.

- ***Produced capital:*** Machinery and equipment; buildings; intangible assets such as intellectual property; and urban land.
- ***Nonrenewable natural capital:*** Fossil fuels (oil, gas, and hard and soft coal); and minerals and metals (bauxite, cobalt*, copper, gold, iron ore, lead, lithium*, molybdenum*, nickel, phosphate rock, silver, tin, and zinc).[92]
- ***Renewable natural capital:*** Agricultural land (cropland and pastureland); forests (timber;[93] non-wood forest ecosystem services, including recreation, fishing, and hunting; non-wood forest products; and water services, reported by protected area status); mangroves (shoreline protection services); marine capture fisheries (including commercial and artisanal fisheries); and renewable energy* (hydropower).[94]
- ***Human capital:*** The value of skills, experience, and effort by the working population over their lifetime by gender (male and female).
- ***Net foreign assets:*** The sum of a country's external assets and liabilities, such as foreign direct investment and reserve assets.

The inclusion of new assets in CWON is typically determined by their growing economic importance in the emergence of new statistical standards and guidelines. For example, the revised version of the SNA standards, intended to come into effect in 2025, will expand the natural resource asset boundary to include renewable energy assets (Smith and Peszko 2022),[95] treating them with the same as fossil fuels. Reflecting this guidance and their importance for the low-carbon energy transition, this edition of CWON adds an account for hydropower assets (see chapter 6), building on the pilot developed for the previous report (chapter 14 in World Bank 2021). However, due to data limitations it was not possible to include global estimates of solar, wind, and geothermal assets. Similarly, additional data were collected to increase the coverage of metals and minerals of growing economic importance, especially for the renewable energy sector. This resulted in the addition of cobalt, lithium, and molybdenum, increasing coverage from 10 to 13 metals and minerals.

HOW ASSETS ARE VALUED IN CWON

In line with CWON's efforts to align itself where possible with the statistical standards and valuation guidance from the SNA and SEEA, it uses the national accounting "exchange value" concept—the marginal price of an asset times its quantity. Where possible, observed market prices are used to align with SNA and SEEA guidance. Which valuation approach is chosen for each asset type ultimately depends on the available implementation guidance and practice, as outlined further below (for more detail, see World Bank 2024). Moreover, to ensure the CWON database is consistent, several common assumptions are implemented:

- A constant uniform discount rate of 4 percent is used, as in previous CWON reports (following World Bank 2006), wherever discounting is required. This assumption is not ideal, since wealth estimates (especially for renewable natural capital and human capital) may be discounted over long periods of time, making the values sensitive to the choice of discount rate. Moreover, using a uniform discount fails to account for significant country-level differences in economic fundamentals (such as

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[91] CWON 2024 does not cover four countries that were included in the CWON 2021 panel due to missing or incomplete CPI data required for the deflation of financial assets (Turkmenistan, Bolivarian Republic of Venezuela, and Republic of Yemen), or missing renewable energy data (West Bank and Gaza).

[92] According to the SEEA-CF (Table 5.6), for a nonrenewable deposit to be considered an economic asset, it must meet several conditions. First, extraction and sale of material from the deposit must have been confirmed to be economically viable. Second, the feasibility of extraction by a mining operation must have been confirmed. Finally, the extraction must either be actively pursued in an on-production project or anticipated in the foreseeable future in a project approved or justified for development.

[93] According to the SEEA-CF (para 5.346), timber resources are those parts of forests where timber harvesting is legally permitted; that are accessible for harvest; and that contain commercially useful species.

[94] The SEEA-CF does not provide explicit guidance on defining hydroelectric resources. Elsewhere in this report (see chapter 6), these are defined as hydroelectric resources associated with "viable" hydroelectric generation projects. Viable generation projects are those for which the environmental-socioeconomic viability and technical feasibility has been confirmed and development or operation is currently taking place, or sufficiently detailed studies have been completed to demonstrate the technical feasibility of development and operation. Hydroelectric resources that exist at sites where hydroelectric generation plants do not currently exist and none are well advanced in planning do not qualify as assets and are not in scope for measurement in CWON.

interest rates, growth patterns, and risk) and social and individual preferences,[96] as well as differences in risk, scarcity, or environmental or other externalities across assets (Dasgupta 2008; Dietz and Asheim 2012; Gollier 2019; Groom et al. 2022). More research is needed to determine how this might be improved in the future. For now, this edition continues to use a constant uniform discount rate, but presents experimental estimates based on differential discount rates for renewable natural capital in chapter 4.

- Future rents are held constant for all assets at current year (2019) values whenever an NPV-RVM approach is used in CWON. This means that future rents used in the NPV calculation reflect 2019 market conditions, policies, and expectations about the future. This is in line with recommendations in the SEEA-CF on the indirect valuation of natural assets (SEEA-CF, paragraphs 5.133 and 5.134.). Given the infinite number of possible future trajectories of rents, and the wide range of assets and countries in the CWON database, this is the least subjective and most transparent assumption. CWON 2024 has implemented this recommendation consistently across all assets, including for agricultural land and human capital, which included rent forecasts in previous editions of CWON.[97]
- Subsidies are not accounted for in the implementation of the NPV-RVM approach in CWON. According to the SNA and SEEA-CF, subsidies paid by governments to support natural resource production should be deducted from revenues in the calculation of resource rent. However, data on subsidies are difficult to obtain, and are currently only available in the CWON database for marine fish stocks. Like the previous edition of CWON (World Bank 2021), marine subsidies were not deducted in CWON 2024 to ensure consistency across all natural capital assets within the CWON database. CWON's approach of not considering subsidies is aligned with statistical practice (though not with official conceptual guidance), as subsidies are generally not accounted for by statistical agencies when they are compiling official national estimates of resource asset values.[98]

PRODUCED CAPITAL

For the calculation of produced capital stocks, CWON follows SNA guidance and international best practice[99] in employing the perpetual inventory method. This approach requires investment data and information on assets' service lives and depreciation patterns, among other things. Data on produced capital stocks in nominal and real terms compiled using this approach are available for most countries directly from the Penn World Tables (PWT) 10.0.[100] Since the produced capital estimates of the PWT are already reported in real terms using a chained Törnqvist volume index, the estimates are directly comparable to the other real measures computed for this edition of CWON.

The nominal value of urban land is estimated as a fixed proportion of the value of produced capital (equivalent to 24 percent), drawing on Kunte et al. (1998). To estimate the volume index for urban land, data on the physical extent of urban land are taken from the Center for International Earth Science Information Network at Columbia University[101]

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[95] A guidance note (Smith and Peszko 2022) for the treatment of renewable energy as assets was produced by the CWON team as a follow-up to the 15 pilot renewable energy accounts produced by CWON 2021. This guidance note has been reviewed and was endorsed as part of the 2025 SNA revision process: https://unstats.un.org/unsd/nationalaccount/aeg/2022/M21/M21_14_WS11_Renewable_Energy_Resources.pdf.

[96] Groom et al. (2022) find significant differences in social discount rates across countries and international organizations, ranging from 1 percent in Germany to 12 percent used by the Inter-American Development Bank.

[97] The assumption to remove rent growth from the estimation of agricultural land is uncontroversial, as it is aligned with valuation guidance for renewable natural capital from the SEEA. However, human capital estimates using the Jorgensen-Fraumeni lifetime income approach (as used in CWON) typically assume wage growth. However, in the context of CWON, alignment of valuation concepts and methods across all assets is critical to ensure that one asset value is not inflated relative to others.

[98] For example, Statistics Canada's estimates of oil assets do not account for subsidies. The same is true of the UK, Australia, Norway, and other major economies. CWON's approach of not considering subsidies for these assets is thus aligned with official statistical practice.

[99] For example, most OECD countries adopt this method to estimate their capital stocks (Bohm et al. 2002; Mas, Perez, and Uriel 2000; Ward 1976).

[100] For countries without PWT estimates, produced capital stock is constructed using gross capital formation as a proxy for aggregate investment and a depreciation rate of 5 percent.

[101] https://sedac.ciesin.columbia.edu/data/collection/grump-v1.

and the urban population from the United Nations (UN) Population Division's World Urbanization Prospects.[102] Given that urban land data are only available for a subset of years,[103] changes in urban land are proxied by changes in the urban land-to-population ratio multiplied by urban population for each year in the time series between 1995 and 2020.

NONRENEWABLE NATURAL CAPITAL

The SEEA-CF recommends the NPV-RVM approach for the valuation of sub-soil assets.[104] CWON adopts this approach, measuring the value of a nation's stock of fossil fuels, minerals, or metals as the present discounted value of the stream of rents expected until the resource is exhausted. Resource rent is calculated each year for each resource type as the difference between the revenues from resource extraction and the cost of that extraction, including intermediate inputs, labor compensation, and the "user cost" of the produced capital used in the extraction process.[105] Previous editions of CWON followed this approach, but proxied the user cost of capital with data on annual investments in fixed assets. While this proxy may be reasonable in the long term, it will not necessarily reflect user costs in the short term.[106] This edition of CWON developed direct user cost estimates for all sub-soil assets by constructing a historical time series of capital stocks and estimating rental and depreciation rates for each asset.

Nominal asset values for nonrenewable natural capital are estimated by drawing on a wide range of publicly available databases from the International Energy Agency (IEA), the United States (US) Geological Survey and US Energy Information Administration, and the UN Statistics Division, as well as licensed data sources from Rystad Energy, Wood Mackenzie, and S&P. Proven reserve estimates are used as the physical quantities required for the volume index. While the coverage of proven reserves data for oil, gas, and coal is relatively comprehensive, there can be significant data gaps for minerals and metals. Gaps are filled forwards by deducting production and backwards by adding production. The backwards approach is likely to be more accurate, as it would include any past resource discoveries. The forward-filling approach is unable to account for any new discoveries that may have occurred.[107]

RENEWABLE NATURAL CAPITAL

For the valuation of renewable natural capital assets, such as agricultural land, timber, marine fish stocks, and renewable energy, the same NPV-RVM approach used for nonrenewable natural capital is applied, with one important difference. In the case of nonrenewables, the lifetime of the asset applied in the NPV calculation is determined by the ratio of current production to current reserves, while in the case of renewables, the lifetime is simply assumed in all instances to be 100 years.[108]

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[102] https://population.un.org/wup/.

[103] Center for International Earth Science Information Network urban land estimates are only available for the years 2000 and 2015. An urban land to urban population ratio is then calculated for these two years and is linearly interpolated and extrapolated to fill the time series between 1995 and 2020.

[104] The SNA, for its part, does not provide explicit guidance to readers on the valuation of natural resource assets. However, it points readers to the SEEA for additional guidance on the topic, so implicitly also recommends the RVM/NPV approach.

[105] User costs of capital are estimated as "normal" returns to fixed assets plus depreciation.

[106] In the long run, the user cost of capital and investments in an industry are likely to be similar. However, in the short run this is unlikely to be the case, as owners may choose to invest more than they earn (by either borrowing or drawing down corporate savings) or less than they earn depending on where they are in the development of their businesses.

[107] For resources in countries for which production data are available but information on reserves is absent, regional or world averages are used.

[108] An exception to the 100-year lifetime is made in the case of timber resources that are not sustainably harvested, for which the lifetime varies depending on current timber stock size and current rates of harvest. For other renewable resources, a 100-year lifetime captures most of the asset value (with a 4 percent discount rate, the present value of any harvest more than 100 years in the future would be, at most, no more than 2 percent of the nominal value). Growing uncertainty regarding the scale of the impact of climate change on both the economy and the environment may be such that an assumed 100-year asset life is no longer valid for CWON. This is a point that will be considered further in future editions. The impact of climate change on both the economy and the environment may be such that an assumed 100-year asset life is no longer valid for CWON. This is a point that will be considered further in future editions.

This follows the practice of the UK's Office for National Statistics (ONS 2020). It is important to note that the resource rent can be computed from detailed revenue and cost data for marine fish stocks[109] and renewable energy,[110] but data (especially on costs) are more limited for agricultural land and timber. A rental rate is thus applied to the gross value of production (as reported by the UN's FAO) to estimate unit resource rents.[111]

For the valuation of ecosystem assets, the NPV of the annual service flow is estimated using spatial socioeconomic and biophysical data in line with SEEA-EA guidance. For example, for non-wood forest ecosystem services, which include recreation, hunting, and fishing, as well as non-wood forest products, and hydrological services, annual benefits are estimated using spatially explicit regression and machine learning models (Siikamäki et al. 2024). These models draw on value estimates from a systematic literature review, as well as complementary spatial data, socioeconomic data at the country level, and spatial data on ecological and biophysical characteristics. These data are further disaggregated by protection status, providing the first global estimates of the value of protected forest areas. This is an improvement on previous editions of CWON, which proxied the value of protected areas by assuming their next best use was in agriculture. This likely overstated the value of many protected areas, especially in large countries with remote protected areas where no meaningful opportunity for agriculture exists. The current estimate provides a lower-bound estimate of terrestrial protected areas, as it only covers forest ecosystems.

For shoreline protection services provided by mangroves (measured by Global Mangrove Watch),[112] the expected benefits of averted damages to property are estimated annually using process-based storm and hydrodynamic models to identify the area and depth of flooding (Menéndez et al. 2024). By running a scenario analysis for different storm frequency events (such as storms every 5, 25, or 100 years) with and without mangroves, a probabilistic distribution of flood damages and avoided damages is derived (for more detail, see chapter 8). These data can then be overlaid with spatialized produced capital from the PWT[113] to estimate annual expected benefits and, subsequently, the NPV of the asset.

For renewable natural capital assets, data on physical volumes needed to compute real wealth measures are generally available. For example, the CWON database includes hectare measures for agricultural land, forest and mangrove areas, and the generation capacity of hydropower plants. The only physical measures not already included in the CWON database prior to this edition were estimates for marine fish stocks. Biomass estimates of major exploited species in a country's exclusive economic zones (EEZs) were derived by the Sea Around Us initiative, using a suite of methods to reconstruct fisheries catches for the 1950–2018 period and complement them with stock assessments performed previously by others (Sumaila et al. 2024).

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[109] The resource rent estimates for wild capture marine fish stocks are produced using data on landed values and prices from FAO and the Sea Around Us reconstruction database (www.seaaroundus.org) as well as the fishing cost database from the Fisheries Economics Research Unit at the University of British Columbia (Lam and Sumaila 2021).

[110] The resource rent estimates for hydropower are estimated using generation data from the International Renewable Energy Agency (IRENA; https://www.irena.org/Data/Downloads/IRENASTAT) and the UN Energy Statistics database (http://data.un.org/Data.aspx?d=EDATA&f=cmID%3aEC), price data from the IEA's Energy Prices database (https://www.iea.org/data-and-statistics/data-product/energy-prices#overview), and cost data from IRENA's regional investment cost estimates (https://www.irena.org/Publications/2023/Aug/Renewable-Power-Generation-Costs-in-2022).

[111] For agricultural land, the rental rate is proxied by country- and decade-specific land cost shares provided by the Agricultural Productivity database of the US Department of Agriculture (https://www.ers.usda.gov/data-products/international-agricultural-productivity/). For timber, the rental rate is proxied for by the ratio of unit rents to the export unit value using adjustment factors based on Applied Geosolutions (2016).

[112] www.globalmangrovewatch.org.

[113] To estimate spatialized produced capital estimates, the per capita capital stock data are multiplied with the European Commission's Global Human Settlement Layer (https://ghsl.jrc.ec.europa.eu/ghs_pop2019.php), which records the global distribution of population at a 250 meter resolution.

HUMAN CAPITAL

There is no single internationally accepted method for the valuation of human capital. However, the lifetime income approach developed by Jorgenson and Fraumeni (1989, 1992a, 1992b) used in CWON is widely applied by researchers in the field, and is one of the statistical approaches recommended by the ongoing 2025 SNA revision process.[114] According to this approach, human capital is estimated as the 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).[115] The implementation of the lifetime income approach requires data from many sources, including data on population by age and gender from the UN's World Population Prospects;[116] employment and labor force participation from the ILO and PWT; survival rates from the Global Burden of Disease Study;[117] and education and earnings profiles from the UN, harmonized household and labor force surveys of the World Bank's International Income Distribution Database and Global Labor Database, as well as the Luxembourg Income Study.[118]

Estimating human capital involves several steps. The first step is to use the standard Mincer equation to estimate private returns per year of schooling using survey data from the International Income Distribution Database, Global Labor Database, and Luxembourg Income Study, and to construct a matrix of expected earnings by age, gender, and education level. However, since these returns include only wages, they need to be scaled up to account for additional benefits workers earn as part of their overall compensation. This is done using data from the SNA. Moreover, since total labor income consists of both the incomes of the employed and self-employed,[119] the latter is estimated using data from the SNA and PWT. After some gap filling, the survey data are adjusted to population estimates from the UN to make sure they represent a country's population. Subsequently, the lifetime income (adjusted by survival rates and a discount factor) can be calculated for the representative individual (aged 15–65) by age, gender, and education. Lastly, these lifetime income profiles are multiplied by the corresponding number of people in a country to compute the human capital stock by age, gender, and education.

To compute human capital in real terms, quality-adjusted labor force data disaggregated by gender are used as a "volume" measure. The labor force data are taken from the ILO and adjusted for the changing educational composition of the labor force, or "quality," by multiplying these volumes by the PWT's human capital index (HCI).[120] This allows us to approximate the average human capital per worker. The nominal human capital estimates (disaggregated by gender) are then used in the Törnqvist volume index to estimate human capital in real terms.

NET FOREIGN ASSETS

Net foreign assets are a measure of the foreign assets and liabilities held by a country's residents, which is calculated as the sum of a country's external assets and liabilities, such as foreign direct investment and reserve assets. Estimates of net foreign assets are mostly obtained directly from the External Wealth of Nations (EWN) Mark II database[121] developed by Lane and Milesi-Ferretti (2007, 2018).

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[114] The endorsed valuation guidance for the SNA 2025 revision process can be found here: https://unstats.un.org/unsd/nationalaccount/RADOCS/ENDORSED_AI1_Valuation_Principles_Methodologies.pdf.

[115] That is, CWON estimates the lifetime income of a representative worker with a given educational background, experience, and gender. Real wages for future earnings for, say, a 30-year-old female worker when she is 50 are set equal to the wages of female workers that are currently 50 with the same educational background.

[116] https://population.un.org/wpp/.

[117] http://www.healthdata.org/gbd/2019.

[118] https://www.lisdatacenter.org/our-data/lis-database/.

[119] The economic role of the self-employed can be especially important in many low- and middle-income countries where subsistence agriculture and informal economy are very common.

[120] https://www.rug.nl/ggdc/productivity/pwt/?lang=en.

[121] https://www.brookings.edu/research/the-external-wealth-of-nations-database/.

The EWN database provides estimates of net foreign assets from 1970 to 2020 for 214 economies. Lane and Milesi-Ferretti primarily draw on reported international investment positions data from individual countries' balance of payment statistics, disseminated by the International Monetary Fund (IMF). The sole conceptual difference is the EWN database excludes central bank gold holdings from financial assets (since they are not a claim on another country). Otherwise, definitions for each component of net foreign assets are official definitions taken from the IMF's *Balance of Payments and International Investment Position Manual* (IMF 2009). To deflate net foreign assets, CPI is used, as discussed previously. Deflation by CPI is justified since financial assets can be viewed as resources available for consumption.

CONCLUSIONS

The main methodological innovation introduced with this update of the CWON database is the use of the Törnqvist volume index to compute real wealth values. Changes in real comprehensive wealth per capita measured in this way provide critical information to policy makers on the sustainability of economic progress. They signal whether the productive base of the economy is growing or shrinking over time (due to changes in the volume of assets) and the extent to which the scarcity and productivity of these assets is changing relative to other assets (through relative price changes). This shift to a volume-based index is in line with international statistical guidance and best practice and is a significant methodological improvement on previous editions of CWON, which used the GDP deflator.

However, there are several methodological and measurement concerns that could not be addressed as part of this update due to time and resource constraints. Future efforts should consider addressing the following:

- ***Quality adjustments to asset volumes:*** The current volume measures used in the Törnqvist volume index are not corrected for the "quality" of the asset (except for the produced capital estimates from the PWT). Such quality adjustments are critical, as they may reinforce or offset observed trends in physical volumes. Data constraints currently limit the ability to make such quality adjustments, but future efforts should aim to collect the required information.
- ***Constrained discount rate:*** The current edition uses a constrained, uniform discount rate. Future efforts should explore the possibility of using differential discount rates, which could vary over time and across assets and countries. Such a revision should build on the guidance and experience of statistical and government agencies around the world, as well as academic literature on social discounting.
- ***Lifetime of renewable resources:*** CWON 2024 continues past practice of valuing all renewable natural assets using an assumed asset life of 100 years (except where harvests are known to be unsustainable). This assumption may require revisiting given that climate change is impacting the environment and the economy more quickly and seriously than anticipated. It may be more realistic to assume that renewable resource rents will flow unchanged for a shorter period. Further research would be required to determine whether a new value could be identified and applied to all renewable resources or whether different lifetimes might be appropriate for different resources.
- ***Accounting for subsidies:*** Subsidies paid by governments to support natural resource production should be accounted for when estimating resource rent. It is recommended that a data assessment be conducted to identify available global subsidy data sources for all natural resource assets.
- ***Urban land:*** Current urban land values are estimated by applying a time-invariant, global factor of 0.24 to the value of produced capital assets from the PWT, based on Kunte et al. (1998). A growing body of evidence suggests this assumption is not well supported, as the actual share (when measured) fluctuates considerably over time and

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122 The APO Productivity Database provides estimates of the value and quantity of land used in production for 25 Asian countries. The OECD also reports land data for 16 out of 37 countries.

differs markedly across countries. The recommendation is to conduct an assessment to determine for which countries urban land value data are readily available[122] and to develop an approach for estimating comparable values for the rest of the world.

- ***Timber:*** The current approach to valuing timber assets uses rents derived from a rental adjustment factor based on timber export prices. The recommendation is to adopt the NPV-RVM approach instead. This will require a data assessment, including the identification of internationally comparable data on revenues from timber production and the associated costs for intermediate inputs, labor, and fixed assets.
- ***Protected areas:*** The current edition of CWON provides the first global estimates of the value of forest protected areas using a meta-regression analysis combined with geospatial data. Future work should explore how to expand these estimates to cover non-forest and marine protected areas.

Lastly, it is important to point out that the CWON 2024 wealth values provide a conservative baseline estimate in line with standard statistical practice, and do not account for future policy actions or changes in market conditions due to, for example, climate change. Modelling is needed to explore possible "what if" scenarios. To facilitate the use of the CWON data in such a modelling exercise, this edition will not only make publicly available the final wealth estimates in real and nominal terms, but also, where possible, the input data and associated statistical code used to derive the wealth estimates. Users of the CWON data will thus be able to modify the input data as well as the assumptions used to derive the wealth estimates, including assumptions about future rent growth. Access to the underlying data and code may be valuable to researchers wishing to compile comprehensive wealth estimates for individual countries using national, rather than global, data. The relevant input data and statistical code can be accessed through the World Bank's website.

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[123] For licensed data, dummy datasets will be made available.

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Annex A1: Methodological Choice to Measure Real Wealth in CWON 2024

WHY MEASURING WEALTH IN REAL TERMS USING A TÖRNQVIST VOLUME INDEX IS APPROPRIATE

The primary objective of any measurement of activity in “real” terms is separating price and volume effects. By removing the general price (inflation/deflation) effect, the real measure will only capture the volume and relative price effect. One way of doing this is by using an appropriate price index, matching the content of the nominal series, to remove general price changes and isolate volume movements, accounting for changes in relative prices. An even better way is to draw on physical quantity data in volume indexes. This best practice is adopted by many national statistical offices, like Canada and the United States, where physical volumes are used whenever available to estimate, for example, elements of GDP in real terms.

This edition of CWON computes real wealth measures using a Törnqvist volume index method, where volume changes, whether arrived at via deflation techniques or physical volume indicators, are weighted by nominal shares in adjacent periods. The current approach directly captures:[124]

- Changes in relative volumes due to the depletion or accumulation of assets.
- Changes in relative prices due to changes in productivity or relative scarcity.
- Changing substitution patterns over time through cross price and cross volume affects.

The Törnqvist volume index accounts for changing substitution patterns, which is fundamental to the analysis of sustainability, as substitution opportunities are affected by changes in the relative scarcity of assets. This new approach is aligned with international best practice by national statistical offices and leading data initiatives, like the PWT. In fact, the PWT uses physical volumes to estimate produced capital in real terms using a chained Törnqvist volume index,[125] which has been the main source of data for CWON’s produced capital estimates. Using the same approach for all other asset classes ensures consistency in methodological choices across produced, natural, and human capital.

WHY MEASURING WEALTH IN REAL TERMS USING A PRICE-BASED DEFLATOR IS INAPPROPRIATE

The GDP deflator only covers current flows of domestic production (not consumption) within a given country and excludes all imported goods or services. While it may be appropriate to use an overall inflation indicator to understand the evolution of the real purchasing power of national wealth (or extended, comprehensive wealth) as a store of value, a domestic demand deflator would be preferrable or, if that is unavailable, a deflator for household consumption expenditure/CPI. The GDP deflator is inappropriate in this context, since it does not match the content of the likely use for national wealth (final domestic demand).

Moreover, even when applying other price-based deflators, there are concerns that they will not be able to capture changes of wealth in real terms. If a general indicator of inflation is used in deflation, changes in real wealth over time will be distorted by short-term price volatility. These are removed with a chained volume index that continuously captures relative price changes throughout the time series. Second, given that many countries compute real GDP with the price weights of a fixed base period, resulting GDP

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[124] For more technical details on the properties of the Törnqvist index, please refer to Dumagan (2002) and Diewert (1992).

[125] The methodology is outlined in Feenstra et al. (2015).

implicit price deflators assume that cross price or cross volume effects are the same at the beginning and end of the accounting period. Such a process cannot remove substitution effects correctly if these patterns are changing over time, which is likely as assets become relatively scarcer. The current approach for estimating wealth in real terms, on the other hand, captures the necessary cross price and volume effects, since it uses a chained index, with an ideal index form (that is, the Törnqvist index).[126]

To deflate economic indicators (GDP, wealth) in the context of sustainability, physical volumes are ideal and in line with economic measurement principles. The chosen index form for the volume measure is a chained Törnqvist index (which is very similar to the chained Fisher ideal index used, for example, for quarterly GDP estimates in the United States), which continuously accounts for changing substitution patterns and factors in changes in relative prices in the weighting of volume measures in each successive period.

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[126] Diewert (1992) shows that a superlative index like the Törnqvist index is a second-order approximation to the expenditure function, which means that it allows for changes between periods in the nature of the Slutsky matrix and, hence, substitution patterns. A price-based index like a GDP deflator, on the other hand, only provides a first-order approximation, assuming constant substitution patterns.

Annex A2: Compilation of the Törnqvist Volume Index

The Törnqvist volume index for a given set of assets is a weighted geometric mean[127] of the so-called "quantity relatives" of each asset included in the index—that is, the ratio of the quantity (or volume) of the asset in the current time period and its volume in the previous period—weighted by the arithmetic average of the shares of the asset in the total nominal value of all k assets in the current period and the previous period. The generic formula to compute the Törnqvist volume index is as follows.[128]

$$Törn_t = \prod_{a=1}^{k} \left(\frac{q_{a,t}}{q_{a,t-1}}\right)^{\theta_{a,t}} = \left(\frac{q_{1,t}}{q_{1,t-1}}\right)^{\theta_{1,t}} * \left(\frac{q_{2,t}}{q_{2,t-1}}\right)^{\theta_{2,t}} * \ldots * \left(\frac{q_{k,t}}{q_{k,t-1}}\right)^{\theta_{k,t}}$$

where:

- $q_{a,t}$ is the volume of asset *a* in year *t*, where *a*={1,2,…,*k*}
- $q_{a,t-1}$ is the volume of asset a in year *t* -1 and
- $\theta_{a,t}$ is the weight of asset *a* in year *t* for all assets {1,2,…,*k*}

The weight $\theta_{a,t}$ of asset *a* is the arithmetic average of the shares of asset *a* in the total nominal value of all assets included in the index in period *t* and *t* -1, and is defined as

$$\theta_{a,t} = \frac{1}{2}\left[s_{a,t} + s_{a,t-1}\right] = \frac{1}{2}\left[\frac{w^n_{a,t}}{w^n_t} + \frac{w^n_{a,t-1}}{w^n_{t-1}}\right]$$

where:

- $s_{a,t}$ is the share of asset *a* in the nominal value of all assets {1,2,…,*k*} included in the index in year *t*, defined as $s_{a,t} = \frac{w^n_{a,t}}{w^n_t}$
- $s_{a,t-1}$ is the share of asset a in the nominal value of all assets {1,2,…,*k*} included in the index in year t-1, defined as $s_{a,t-1} = \frac{w^{\square}_{a,t-1}}{w^n_{t-1}}$
- w^n_t is the nominal value of all assets {1,2,…,*k*} included in the index in year *t*, defined as $w^n_t = \sum_{a=1}^{k} w^n_{a,t}$ where $w^n_{a,t}$ is the nominal value of asset *a* in year *t*
- w^n_{t-1} is the nominal value of all assets {1,2,…,*k*} included in the index in year *t* -1, defined as $w^n_{t-1} = \sum_{a=1}^{k} w^n_{a,t-1}$ where $w^n_{a,t-1}$ is the nominal value of asset *a* in year *t* -1

Volume as it is used here should be understood to be a physical quantity (or a proxy for a quantity) of a given asset. As an example, the volume of agricultural land assets is measured in hectares and the volume of oil assets is measured in barrels. The purpose of the volume index is to sum the volumes, even though they are measured in different units. This is accomplished by weighting the "quantity relatives" of each asset by their value shares, as described above, rendering them unitless and, therefore, commensurable.

Ideally, asset volumes should reflect the underlying quality of the assets, and how these change over time. As an example, the volume of agricultural land assets should be measured in quality-adjusted hectares; for example, if the per hectare productivity of agricultural land declines by 1 percent annually, the volume of the land also declines by 1 percent annually, even if the total quantity of land (measured in hectares) does not change. As another example, not all workers are equal in terms of their contribution to human capital. Workers that are highly educated generally contribute more to human capital than those with fewer qualifications. Thus, an increase in the number of highly educated workers will benefit human capital more than the same change in unqualified workers. To reflect this, the "volume" of workers should be broken down by level of education (among other characteristics). The global data available for the compilation of CWON do not permit these kinds of distinctions, which is why the human capital index from the PWT[129] is used to approximate the average human capital per worker. Similarly, the produced capital estimates derived from the PWT reflect both quantity and quality changes in the underlying assets. Improving this aspect of the methodology for other types of capital, most notably natural capital, is a goal for the future.

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[127] A geometric mean of a set of values is the n^th^ root of the product of the values, where n is the number of values in the set.

[128] Country notation is suppressed for the sake of clarity in presentation.

However, the above does not mean the index is not sensitive to the issue of asset quality. If markets are functioning properly, changes in the quality of assets will be observed in changes in their relative nominal values. Increases in the number of highly educated workers should, other things being equal, increase the value of human capital relative to other assets. Similarly, losses of prime farmland should decrease the relative value of farmland. Since changes in the volume of assets are weighted in the index by the shares of those assets in the total nominal value of all assets, changes in relative prices will go some way toward reflecting changes in asset quality in the index.

A Törnqvist volume index can be compiled according to the formula above for any period and for any number of individual asset types. In CWON, the period is the calendar year, and the number of assets depends on the specific index within the CWON accounts. The number of assets included in the CWON volume indexes ranges from 1 (in the case of an index compiled for a single asset like hydroelectric resources) to 18 (in the case of the index of all nonrenewable natural capital assets). The volume indexes for each asset type—produced capital, renewable natural capital, nonrenewable natural capital, human capital, and net foreign assets[130]—are then used as inputs into an overall Törnqvist volume index for aggregate comprehensive wealth.

It should be noted that the growth rates of the Törnqvist indexes for the different asset types cannot simply be added together to arrive at the growth rate of the overall index. This is a drawback compared with previous editions of CWON, where the real values of assets were derived by applying a GDP deflator to nominal asset values and overall comprehensive wealth was simply the sum of the real values of each asset type. However, it is important to note that the grouping of assets into asset categories does not affect the overall growth in the index; any combination of assets will yield the same overall change in the index.

To make the Törnqvist volume index easier to interpret, it is "chained" into a time series by selecting a reference year and then expressing other years in terms relative to the reference year. CWON 2024 chose to use 2019 as the reference year.

For the reference year (t=2019), the chained Törnqvist volume index is normalized to 100, that is,

$$Törn\_chained_{2019} = 100$$

For all the years before the reference year, that is, for t<2019, the chained Törnqvist volume index is computed as

$$Törn\_chained_t = \frac{Törn\_chained_{t+1}}{Törn_{t+1}}$$

For all the years after the reference year, that is, for t>2019, it is computed as

$$Törn\_chained_t = Törn\_chained_{t-1} * Törn_t$$

To compute the 1995–2020 time series of real values expressed in "chained prices" or "real terms," the nominal aggregate wealth of the base year (2019) is multiplied by the chained Törnqvist volume index in each year.

Table A2.1 illustrates the calculation of real national comprehensive wealth in chained 2019 US dollars using a Törnqvist volume index for a country with just two assets: farmland and oil.

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[129] https://www.rug.nl/ggdc/productivity/pwt/?lang=en.

[130] As mentioned above, net foreign assets are simply deflated using a CPI.

TABLE A2.1

Example of two asset Törnqvist volume index

	FARMLAND								
YEAR	Farmland area (hectares)	Quantity relative	Nominal asset value (US$ billion)	Share of previous year's nominal national wealth	Share of current year's nominal national wealth	Weight	Weighted quantity relative	Proven oil reserves (barrels)	Quantity relative
	q_t	$\frac{q_t}{q_{t-1}}$	w_t	s_{t-1}	s_t	$\theta = \frac{s_t + s_{t-1}}{2}$	${\frac{q_t}{q_{t-1}}}^{\theta}$	q_t	$\frac{q_t}{q_{t-1}}$
1994	50,000		25		0.357			281,000	
1995	50,056	1.001	25	0.357	0.358	0.358	1.00040	279,169	0.993
1996	50,171	1.002	25	0.358	0.351	0.355	1.00082	276,931	0.992
1997	50,184	1.000	26	0.351	0.341	0.346	1.00009	276,878	1.000
1998	50,189	1.000	27	0.341	0.347	0.344	1.00003	274,977	0.993
1999	50,438	1.005	29	0.347	0.348	0.347	1.00173	274,676	0.999
2000	50,608	1.003	29	0.348	0.334	0.341	1.00114	272,046	0.990
2001	50,790	1.004	30	0.334	0.319	0.327	1.00117	271,670	0.999
2002	50,794	1.000	32	0.319	0.328	0.324	1.00003	271,559	1.000
2003	50,957	1.003	35	0.328	0.337	0.332	1.00106	270,904	0.998
2004	51,196	1.005	35	0.337	0.327	0.332	1.00156	269,910	0.996
2005	51,385	1.004	38	0.327	0.329	0.328	1.00120	268,332	0.994
2006	51,617	1.005	40	0.329	0.317	0.323	1.00146	266,005	0.991
2007	51,854	1.005	43	0.317	0.328	0.323	1.00148	264,761	0.995
2008	52,110	1.005	46	0.328	0.333	0.331	1.00163	263,226	0.994
2009	52,306	1.004	48	0.333	0.325	0.329	1.00123	262,226	0.996
2010	52,458	1.003	48	0.325	0.308	0.316	1.00092	260,943	0.995
2011	52,559	1.002	51	0.308	0.311	0.309	1.00059	258,933	0.992
2012	52,802	1.005	54	0.311	0.314	0.312	1.00144	257,721	0.995
2013	52,993	1.004	58	0.314	0.320	0.317	1.00114	256,469	0.995
2014	53,164	1.003	58	0.320	0.320	0.320	1.00104	255,733	0.997
2015	53,217	1.001	60	0.320	0.307	0.313	1.00031	255,197	0.998
2016	53,320	1.002	61	0.307	0.298	0.303	1.00058	254,402	0.997
2017	53,450	1.002	65	0.298	0.295	0.297	1.00072	253,758	0.997
2018	53,456	1.000	70	0.295	0.295	0.295	1.00003	252,038	0.993
2019	53,660	1.004	71	0.295	0.286	0.290	1.00111	251,033	0.996
2020	53,918	1.005	72	0.286	0.288	0.287	1.00138	250,966	1.000

OIL					WEALTH			
Nominal asset value (US$ billion)	Share of previous year's nominal national wealth	Share of current year's nominal national wealth	Weight	Weighted quantity relative	Nominal national wealth (US$ billion)	Unchained Törnqvist volume index	Chained Törnqvist volume index	Real national comprehen-sive wealth (billion chained 2019 US$)
w_t	s_{t-1}	s_t	$\theta = \frac{s_t + s_{t-1}}{2}$	$\frac{q_t}{q_{t-1}}^{\theta}$			2019 = 100	
45		0.643			70	1.00000		-
46	0.643	0.642	0.642	0.99581	71	0.99621	104.95	262
47	0.642	0.649	0.645	0.99482	73	0.99563	104.49	261
50	0.649	0.659	0.654	0.99988	76	0.99996	104.49	261
51	0.659	0.653	0.656	0.99549	78	0.99552	104.02	260
54	0.653	0.652	0.653	0.99929	83	1.00101	104.12	260
58	0.652	0.666	0.659	0.99368	88	0.99481	103.58	259
64	0.666	0.681	0.673	0.99907	94	1.00024	103.61	259
66	0.681	0.672	0.676	0.99972	99	0.99975	103.58	259
69	0.672	0.663	0.668	0.99839	103	0.99945	103.52	259
73	0.663	0.673	0.668	0.99755	108	0.99910	103.43	259
78	0.673	0.671	0.672	0.99607	117	0.99726	103.15	258
86	0.671	0.683	0.677	0.99412	125	0.99557	102.69	257
89	0.683	0.672	0.677	0.99683	132	0.99831	102.52	256
92	0.672	0.667	0.669	0.99611	138	0.99774	102.29	256
100	0.667	0.675	0.671	0.99745	148	0.99868	102.15	255
108	0.675	0.692	0.684	0.99665	156	0.99757	101.90	255
112	0.692	0.689	0.691	0.99468	163	0.99527	101.42	254
117	0.689	0.686	0.688	0.99678	171	0.99821	101.24	253
122	0.686	0.680	0.683	0.99668	180	0.99782	101.02	253
124	0.680	0.680	0.680	0.99805	183	0.99908	100.93	252
136	0.680	0.693	0.687	0.99856	196	0.99887	100.81	252
142	0.693	0.702	0.697	0.99783	203	0.99841	100.65	252
155	0.702	0.705	0.703	0.99822	219	1.00000	100.65	252
168	0.705	0.705	0.705	0.99521	239	0.99525	100.17	251
179	0.705	0.714	0.710	0.99717	250	0.99827	100.00	250
179	0.714	0.712	0.713	0.99981	252	1.00119	100.12	250

3 Global and Regional Trends in Wealth, 1995–2020

MAIN MESSAGES

- A key measure of economic progress is how the real wealth per capita of a nation—consisting of produced capital, nonrenewable natural capital, renewable natural capital, human capital, and net foreign assets—changes over time.
- Real wealth per capita grew by 21 percent globally between 1995 and 2020 due to significant increases in human and produced capital. However, while two-thirds of countries in the CWON database saw an increase in their real wealth per capita, 27 countries experienced declines or saw little change. Most of these countries were low-income nations. Some were also fragile and affected by conflict.
- Changes in the composition of the asset portfolio and population growth have driven changes in real wealth per capita. While the accumulation of produced and—to a lesser extent—human capital has kept pace with population growth, renewable natural capital per capita has experienced dramatic declines across the world. Nonrenewable natural capital, on the other hand, has experienced more volatile trends, driven by changes in market conditions, new discoveries, and technological innovations.
- GDP only tells a partial story of economic progress. While most countries are either getting richer and wealthier, or poorer and more impoverished, more than 25 percent of countries have experienced positive GDP per capita growth while their real wealth per capita has declined. To ensure their economic growth is sustainable, it will be critical for these countries to continue investing in a diversified asset base.

INTRODUCTION

A key measure of progress is how the real wealth of a nation—consisting of produced capital, nonrenewable natural capital, renewable natural capital, human capital, and net foreign assets—changes over time relative to population growth. As long as real wealth per capita does not decline, economic development is weakly sustainable (Hartwick 1978; Hamilton and Clemens 1999). As in previous editions of CWON, the wealth measurement uses the best possible global data sources available and (where possible) methods aligned with the internationally accepted statistical standards and guidelines of the System of National Accounts (SNA; EC et al. 2009) and its extension, the System of Environmental-Economic Accounting (SEEA; UN et al. 2014, 2021). Different to previous editions, changes in real wealth per capita (computed using a volume-based index; see chapter 2) are now driven by changes in the physical volumes (for example, a country's fossil fuel reserves, fish stocks, or labor force) and relative price changes, reflecting changes in the relative scarcity of the stocks being measured, changes in the availability of potential substitutes or complements, or institutional and policy changes.

The interpretation of changes in CWON's real comprehensive wealth per capita metric depends on how wealth is measured. If one could measure wealth comprehensively, changes in real wealth per capita could be interpreted as welfare changes (see chapter 1). However, data constraints limit the ability of the CWON work program to include key assets, most notably renewable natural capital and ecosystem assets. The CWON database captures most of the productive asset base of the economy because it includes all key assets of the SNA non-financial balance sheet as well as human capital and key ecosystem services that support economic production. Therefore, changes in real wealth per capita can proxy for changes in the overall sustainability of economic progress. Increases in real wealth per capita over time would suggest that a country's economic progress is sustainable, while declines would indicate that current production and consumption choices are eroding the productive base and, thus, diminishing the future opportunities available to the country in question.

This chapter provides an overview of how the wealth of nations has evolved from 1995 to 2020. It covers the main trends in real wealth per capita across income groups, given that there are large disparities in wealth levels and trends by income. It also reports differences across World Bank regions, given the diversity of asset portfolios and development experiences across the globe. Moreover, given that conflicts can have significant impacts on a country's wealth (World Bank 2023a), trends are also reported separately for countries using the World Bank's fragility, conflict, and violence (FCV) classification.[131] Next, the chapter analyzes the composition of wealth and how the main asset categories have evolved over time. The final section draws some conclusions on how changes in real wealth per capita can provide new insights on the sustainability of economic progress and complement more standard macroeconomic measures, such as GDP.

GLOBAL TRENDS IN WEALTH PER CAPITA BY REGION, INCOME GROUP, AND FCV STATUS

Wealth is highly concentrated in rich countries, with high-income countries making up more than two-thirds of total wealth in nominal terms in 2020 (Figure 3.1). The wealth disparities are significant: upper-middle-income countries make up nearly a quarter of global wealth, while the rest of the world, where half of the world's population lives, accounts for merely 7 percent. Moreover, there is no evidence that this wealth gap has been closing significantly over the last quarter of a century, especially for the poorest countries. While middle-income countries were able to almost double their share in wealth—from 11 to 23 percent for upper-middle-income countries and 4 to 6 percent for lower-middle-income countries—the share of low-income countries has largely remained the same at less than 1 percent of global wealth since 1995.

From a regional perspective, wealth is concentrated in North America (the United States and Canada), Europe (Germany, France, and the United Kingdom), and East Asia and the Pacific (China and Japan), accounting for 65 percent of global wealth. Meanwhile, the other four regions, comprising Latin America and the Caribbean, the Middle East and North Africa, Sub-Saharan Africa, and South Asia, where more than half of the world's population lives, only account for 14 percent of global wealth. These wealth disparities also persist if adjustments are made for price-level differences across countries; the adjustments mainly reduce the gap between high- and upper-middle-income countries (as illustrated in annex A3).

From a sustainability perspective, trends in real wealth per capita are most important. Real wealth per capita has grown globally due to significant increases in human and produced capital (Panel a, Figure 3.2), driven by rapid urbanization and growing female participation in the labor market. The growth in real wealth per capita relative to 1995 is particularly pronounced for the Middle East and North Africa region (97 percent increase) and Latin America and the Caribbean (66 percent increase). This growth is largely attributed to substantial rises in human capital (82 percent and 61 percent, respectively) and produced capital (138 percent and 83 percent, respectively) in these regions, but has not resulted in substantial increases in their share in global wealth (which stood at 4 percent and 3 percent, respectively, in 2020; Panel b of Figure 3.2). However, the accumulation of real wealth in some regions, most notably Sub-Saharan Africa, has not grown at the same speed as their populations. While there were periods of growth in real wealth per capita between 1995 and 2010, real wealth per capita has been declining in Sub-Saharan Africa since then due to depletion and overexploitation of natural capital (Panel c, Figure 3.2).

While two-thirds of the 151 countries in our sample have experienced growth in real wealth per capita over the last quarter of a century, 27 countries have experienced declines or have seen little change (Figure 3.3). Most countries have been able to increase their real wealth per capita, some of them substantially, primarily due to growth in human capital.

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[131] The "FCV" concept groups three issues that are often related: (i) deep governance issues and state institutional weaknesses; (ii) situations of active conflict; and (iii) high levels of interpersonal and/or gang violence (World Bank 2023a).

FIGURE 3.1

Distribution of global wealth, by income group, 1995 and 2020

Panel a: Global wealth, 1995

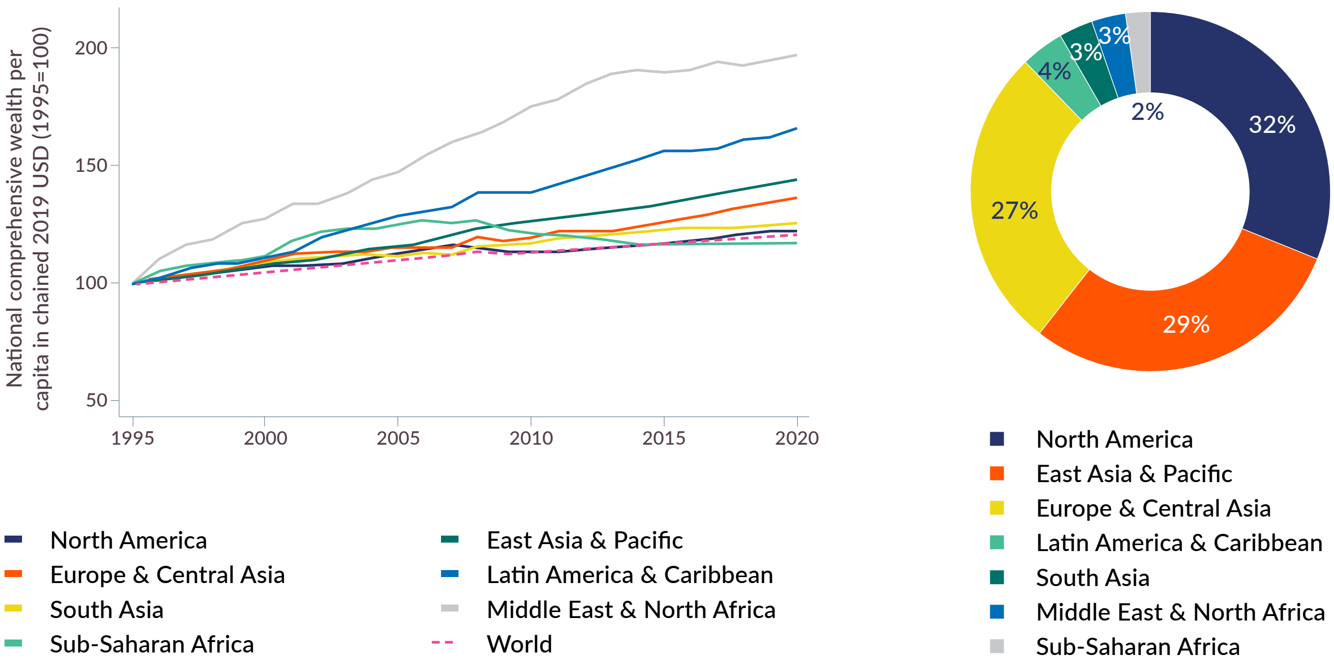
Panel b: Global wealth, 2020

Source: World Bank staff estimates.

Note: Wealth is measured in current US dollars. World Bank income classifications groupings are used and kept constant from the latest year in the dataset. Changes in shares reflect changes in wealth for a consistent group rather than classification changes.

FIGURE 3.2

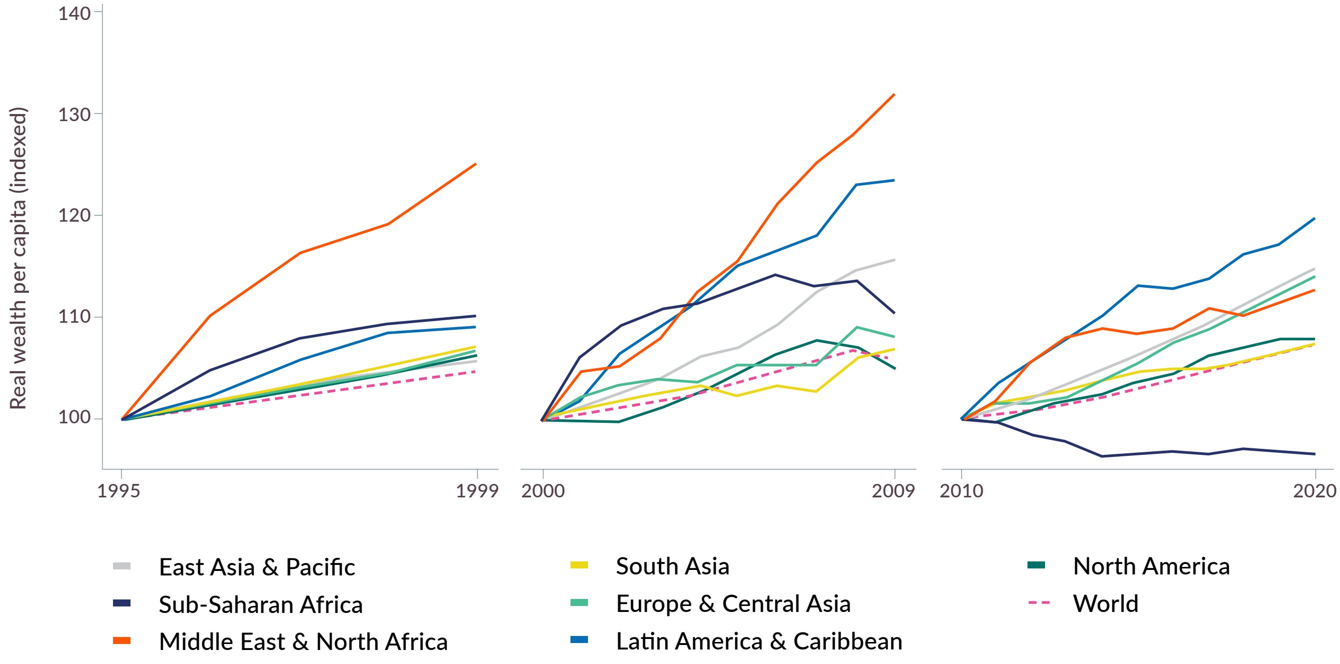
Real wealth per capita, by region, 1995–2020



Panel a: Trends in real wealth per capita, by region, 1995–2020 (1995=100)

Panel b: Nominal wealth shares, by region, 2020

Panel c: Trends in real wealth per capita, decadal, 2000 and 2010 (1995=100)



Source: World Bank staff estimates.

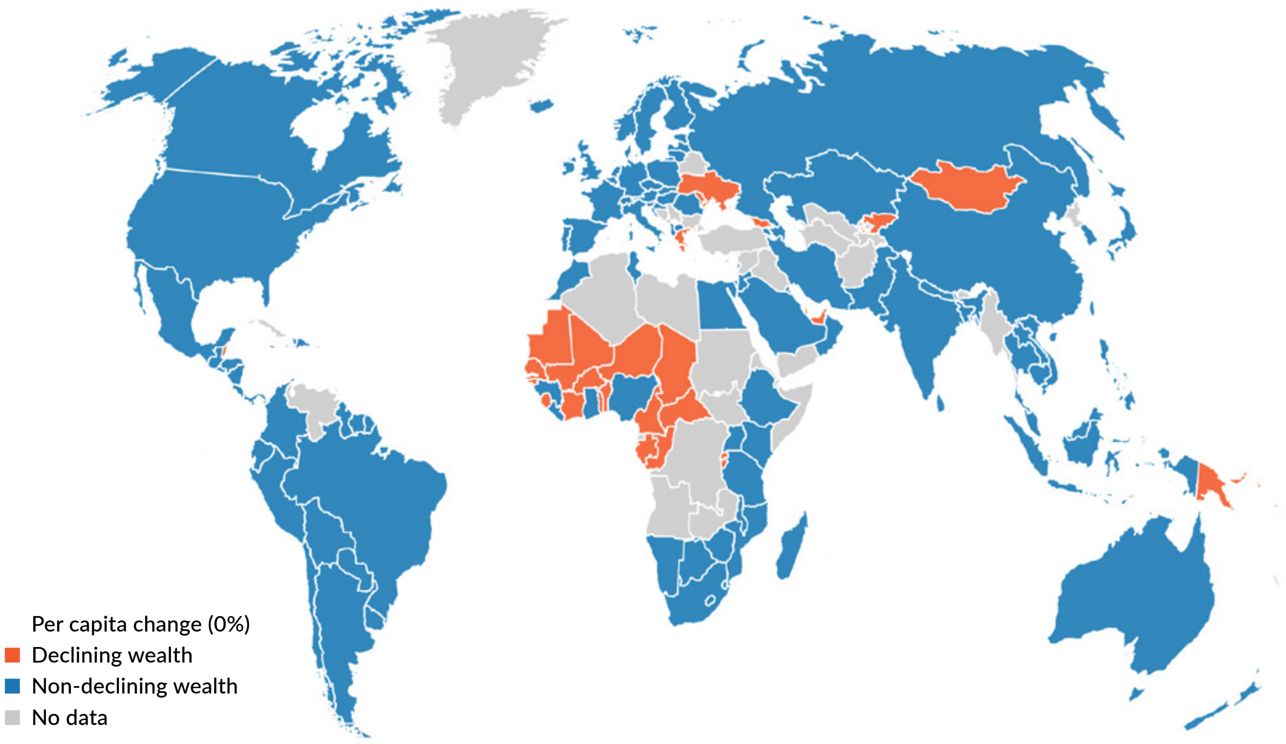
Note: Real wealth per capita is computed using the Törnqvist volume index. For the relative volume changes, chained Törnqvist volume indexes are used for produced capital, nonrenewable and renewable natural capital, human capital, and net foreign assets (for net foreign assets, the nominal asset value is deflated using the CPI). The weights are calculated using their respective nominal asset value relative to nominal wealth. The Törnqvist volume index for wealth is then chained with a base year of 2019 and real wealth is computed using the nominal wealth estimate for 2019. Regional wealth per capita is computed as a sum of real wealth for the countries in the region divided by the regional population. In Panel a, changes in real wealth per capita for each region are reported relative to 1995 (set equal to 100). In Panel b, nominal wealth is measured in current US dollars and shares are reported in percent. In Panel c, the time period is segmented into three decadal periods, with the first assigned 5 years as the total time series is 25 years.

As human capital makes up nearly two-thirds of global wealth, any increases in human capital due to higher labor force participation or increasing educational attainment will translate into substantial increases in real wealth per capita. However, several countries across regions and income groups have experienced declining wealth per capita, most notably many low-income countries, especially in Sub-Saharan Africa (Figure 3.3). Such a decline in real wealth per capita signals that economic progress is unsustainable.

One possible driver of the declines in real wealth per capita could be conflict, with more than 40 percent of the countries on an unsustainable development path being classified as FCV countries. In fact, fragility, conflict, and violence can have significant impacts on wealth by limiting investments in better infrastructure, increasing the depletion of natural resources, or constraining the potential of accumulating human capital. In 1995, each person living in FCV countries had an average wealth of $15,650, compared to $103,000 in the rest of the world's countries. This shows a staggering wealth inequality in the world that continues to worsen. In the following 25 years, wealth per capita in non-FCV countries reached $128,000, but in FCV countries it only increased to about $15,970. This increasing wealth inequality can be observed in Figure 3.4, where non-FCV countries have experienced a steady increase in real wealth per capita, while the early gains in FCV countries were offset by subsequent declines, leading to an average increase of merely 2 percent between 1995 and 2020.

FIGURE 3.3

Countries with declining and non-declining real wealth per capita, 1995–2020

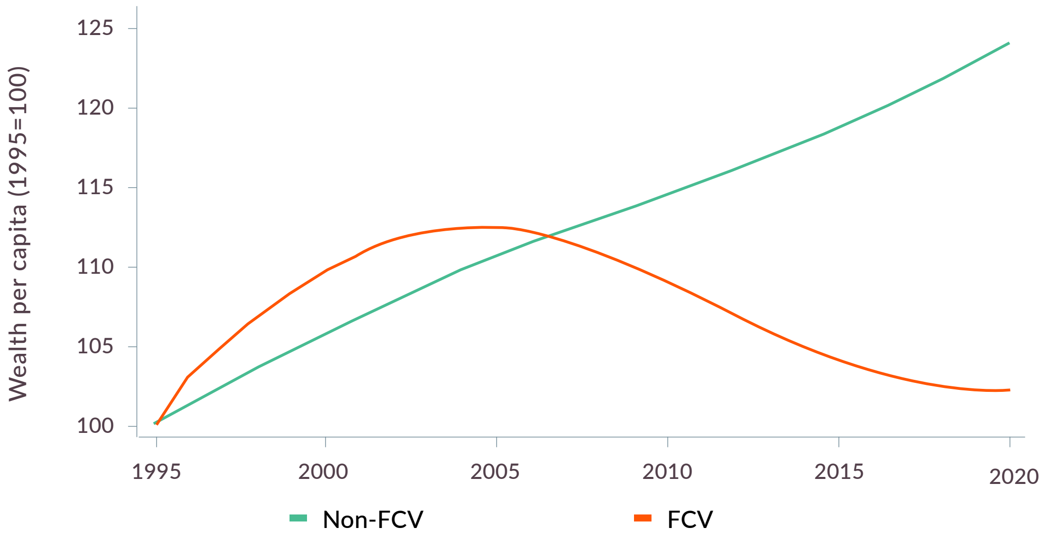


Source: World Bank staff estimates.

Note: Percent changes in real wealth per capita are computed for the 1995–2020 period. This figure distinguishes between countries that experienced declining wealth (percent change < 0) vs. non-declining wealth (percent change >= 0) during this period but does not compare wealth per capita nominal values directly. As discussed throughout the report, non-declining wealth per capita is a minimum requirement for sustainable economic growth, although not a sufficient condition.

FIGURE 3.4

Trends in real wealth per capita, by FCV status, 1995–2020 (1995=100)



Source: World Bank staff estimates.

Note: Real wealth per capita is computed using the Törnqvist volume index. For details on the computation of global real wealth per capita refer to the notes of Figure 3.2.

GLOBAL TRENDS IN PER CAPITA WEALTH BY ASSET CATEGORY

The growth in real wealth per capita is driven by changes in the composition of the asset portfolio relative to population growth, with increases in produced and human capital driving change over the last quarter of a century. Four main asset categories make up CWON's wealth measure: produced capital, nonrenewable and renewable natural capital, and human capital.[132] Human capital, which makes up the largest share of nominal wealth at 60 percent in 2020 (Panel b, Figure 3.5), has increased by about 9 percent in per capita terms relative to 1995 (Panel a, Figure 3.5). Produced capital is the second-most important asset category, making up one-third of global nominal wealth. Despite the fast-growing world population, produced capital per capita has accumulated most rapidly, with an increase of 47 percent in per capita terms between 1995 and 2020.

However, the trends are starkly different for the components of natural capital. Nonrenewable natural assets, which make up 2 percent of global wealth, have slightly declined in per capita terms over the same period. This is the most volatile asset category, where years of growth are followed by sudden losses of value, partly driven by changes in the underlying asset base due to discoveries and technological innovations as well as price fluctuations. Meanwhile, renewable natural capital, which should be able to regenerate itself if managed sustainably, has declined by more than 20 percent in per capita terms over the past quarter of a century. This decline and the capital's 6 percent share in global nominal wealth are likely underestimates, as data and conceptual concerns limit the ability to measure and value renewable natural capital comprehensively.

These global trends mask significant differences across income groups. Renewable natural capital per capita has declined dramatically in real terms across all income groups, but the largest relative declines are observed for the lowest levels of development. Low-income countries lost nearly half of their real renewable natural capital per capita over the last 25 years, while lower-middle-income countries saw a one-third reduction. For nonrenewable natural capital per capita, the trends are even more pronounced, with substantial declines for low-income and lower-income countries (60 percent and 17 percent, respectively) but increases at higher levels of development (30 percent in high-income countries). For produced and human capital, all income groups experienced growth, but the relative magnitude of the increases varies, especially for per capita produced capital. For example, upper-middle-income countries saw the largest relative increase of 234 percent relative to 1995, followed by low- and lower-middle-income countries (143 percent and 97 percent, respectively).

RENEWABLE NATURAL CAPITAL

Although renewable natural capital wealth is increasing in some parts of the world (Panel a, Figure 3.7), no region's growth was fast enough to keep up with population growth, leading to drastic declines in per capita terms (Panel b, Figure 3.7). Sub-Saharan Africa and the Middle East and North Africa have experienced the largest declines in renewable natural capital wealth per capita since 1995 of about 40 percent, with South Asia losing about one-third. Regions with high-income countries have seen the smallest losses, though these are still substantial, ranging from 8 percent for Europe and Central Asia to 18 percent for North America. The declining value of renewable natural capital per capita is driven by an overexploitation across almost all renewable natural resources included in this report—agricultural land, forests, marine capture fisheries, and mangroves. The only exception is hydropower (added with this edition), which saw a steady increase in per capita wealth over time.

The degradation trends vary greatly across different forms of renewable natural capital, with the most dramatic declines observed in marine fish stocks per capita. Marine fish stocks per capita have dropped by more than 45 percent in real terms since 1995, almost two times faster than mangroves and timber (Panel a, Figure 3.8). This has nearly reduced its contribution to the value of renewable natural capital to zero (Panel b, Figure 3.8).

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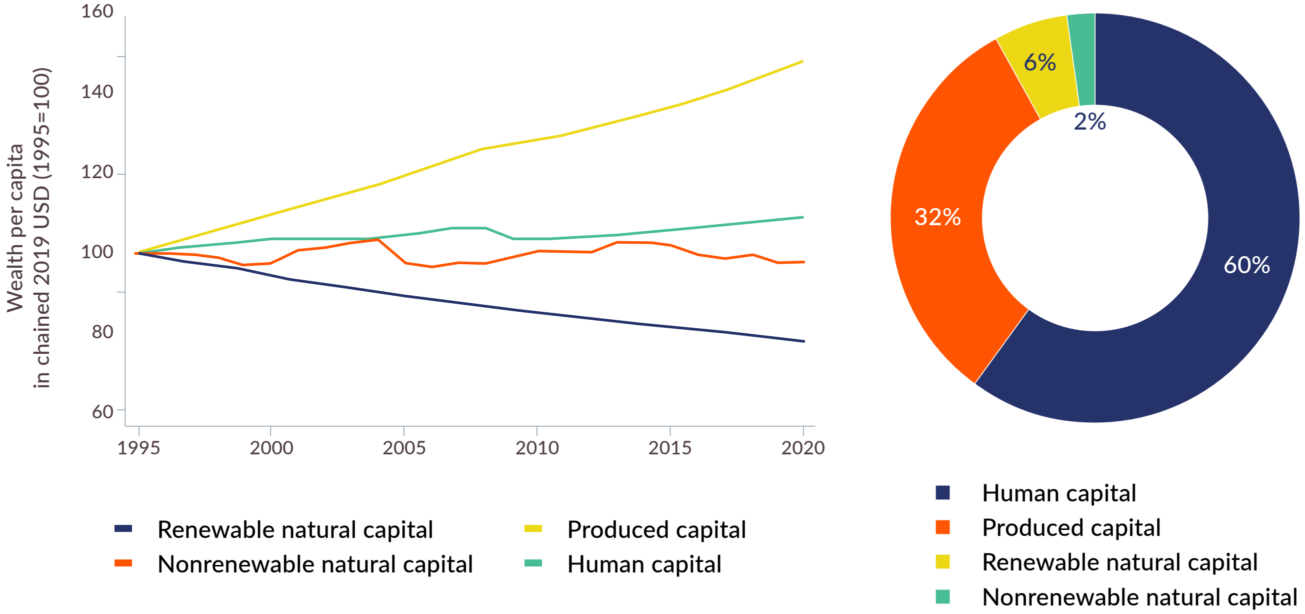
[132] Net foreign assets are not included in this global comparison because, by definition, global external assets equal global external liabilities. That this cannot be shown is an empirical discrepancy due to inconsistent reporting, as discussed by Lane and Milesi-Ferretti (2007). Lane and Milesi-Ferretti found that an underreporting of external assets relative to external liabilities led to a similar magnitude of global discrepancy in net foreign assets as is found for national current accounts (trade) and financial accounts (financial flows).

FIGURE 3.5

Wealth per capita, by asset category



Panel a: Trends in real wealth per capita, by asset category, 1995–2020 (1995=100)

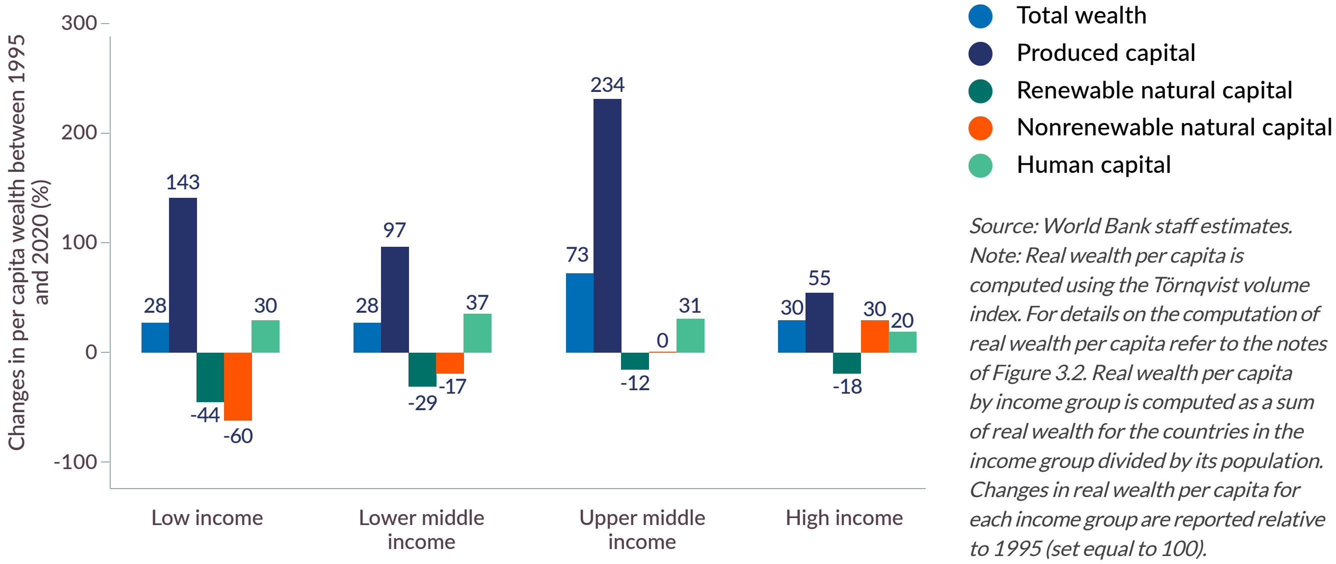
Panel b: Nominal wealth shares, by asset category, 2020

Source: World Bank staff estimates.

Note: Real wealth per capita by asset category is computed using the Törnqvist volume index. For the relative volume changes, physical measurements of the assets in each asset category are used. The weights are calculated using their nominal asset value relative to the nominal value of their respective asset category. The Törnqvist volume index for each asset category is then chained with a base year of 2019 and the real value of each asset category is computed using the nominal value of each asset category for 2019. The global real value of each asset category (measured in chained 2019 US dollars) is computed by summing across all countries and dividing by the global population. Changes in real comprehensive wealth per capita for each asset category are reported relative to 1995 (set equal to 100). Nominal wealth is measured in current US dollars and shares are reported in percent.

FIGURE 3.6

Change in wealth per capita, by income group and asset class, 1995–2020



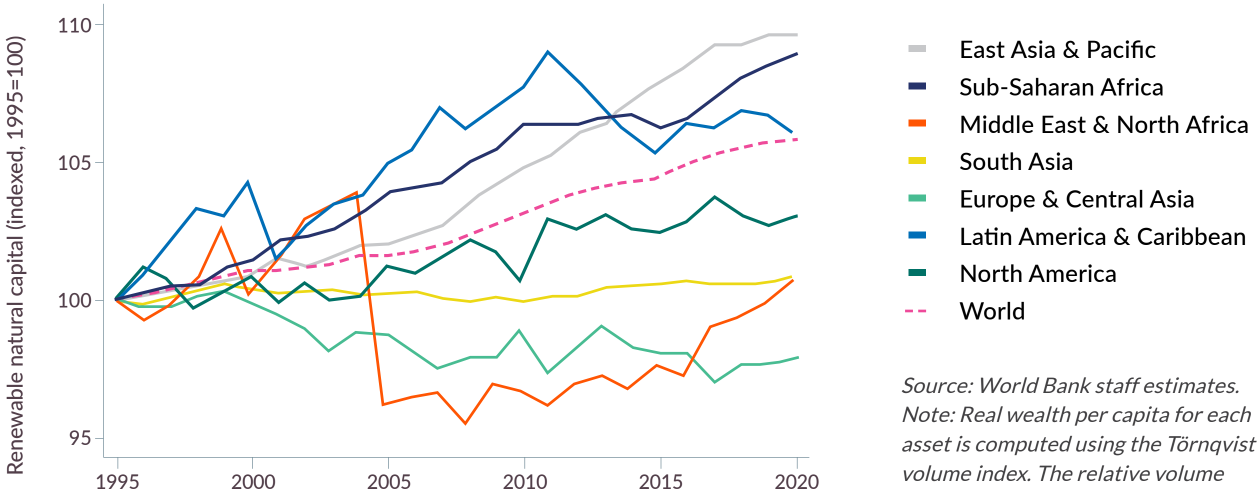
Source: World Bank staff estimates.

Note: Real wealth per capita is computed using the Törnqvist volume index. For details on the computation of real wealth per capita refer to the notes of Figure 3.2. Real wealth per capita by income group is computed as a sum of real wealth for the countries in the income group divided by its population. Changes in real wealth per capita for each income group are reported relative to 1995 (set equal to 100).

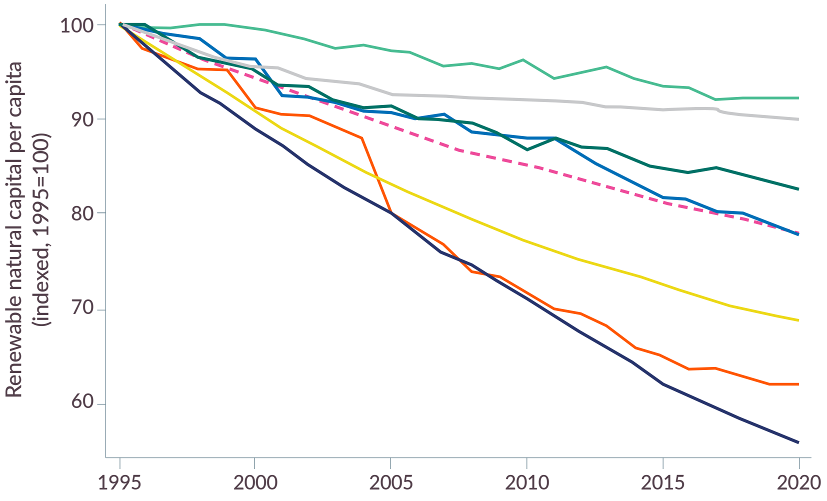
FIGURE 3.7

Trends in renewable natural capital, by region, 1995–2020

Panel a: Renewable natural capital



Panel b: Renewable natural capital per capita



Source: World Bank staff estimates.
Note: Real wealth per capita for each asset is computed using the Törnqvist volume index. The relative volume changes use physical measurements of agricultural land (in square kilometers), timber (in hectares), mangroves (in hectares), non-wood forest ecosystem services (in square kilometers), hydropower (in GWh), and fish stocks (in tons). No weighting is used for measuring individual assets in real terms. The Törnqvist volume index for each asset is then chained with a base year of 2019 and the real value of each asset is computed using the nominal asset value for 2019. Regional renewable natural capital per capita in real terms is computed as a sum of real renewable natural capital wealth for the countries in the region divided by the regional population. Changes in real wealth per capita for each region are reported relative to 1995 (set equal to 100).

In some countries, these declines are even more dramatic. For example, Pakistan has lost more than 66 percent of its marine fish stocks per capita wealth due to overfishing, while Belize has lost about 50 percent of its mangroves per capita value relative to 1995.

Meanwhile, other renewable natural capital components—such as agricultural land, which is the most important component of renewable natural capital (accounting for 73 percent of its global value) and non-timber forest recreation ecosystem services (12 percent)[133]—have experienced similar though less dramatic declines. For example, timber per capita has lost about 53 percent of its value in Sub-Saharan Africa in just 25 years because the continent's forest cover has shrunk by about 9 percent. Notably, renewable energy from hydropower had a remarkable increase of 23 percent over the same 25-year period, making up 7 percent of the overall value of renewable natural capital. It more than tripled for water-abundant countries like Guinea and Vietnam. However, other important renewable energy assets such as solar, wind, and geothermal assets could not be included in this edition due to data limitations.

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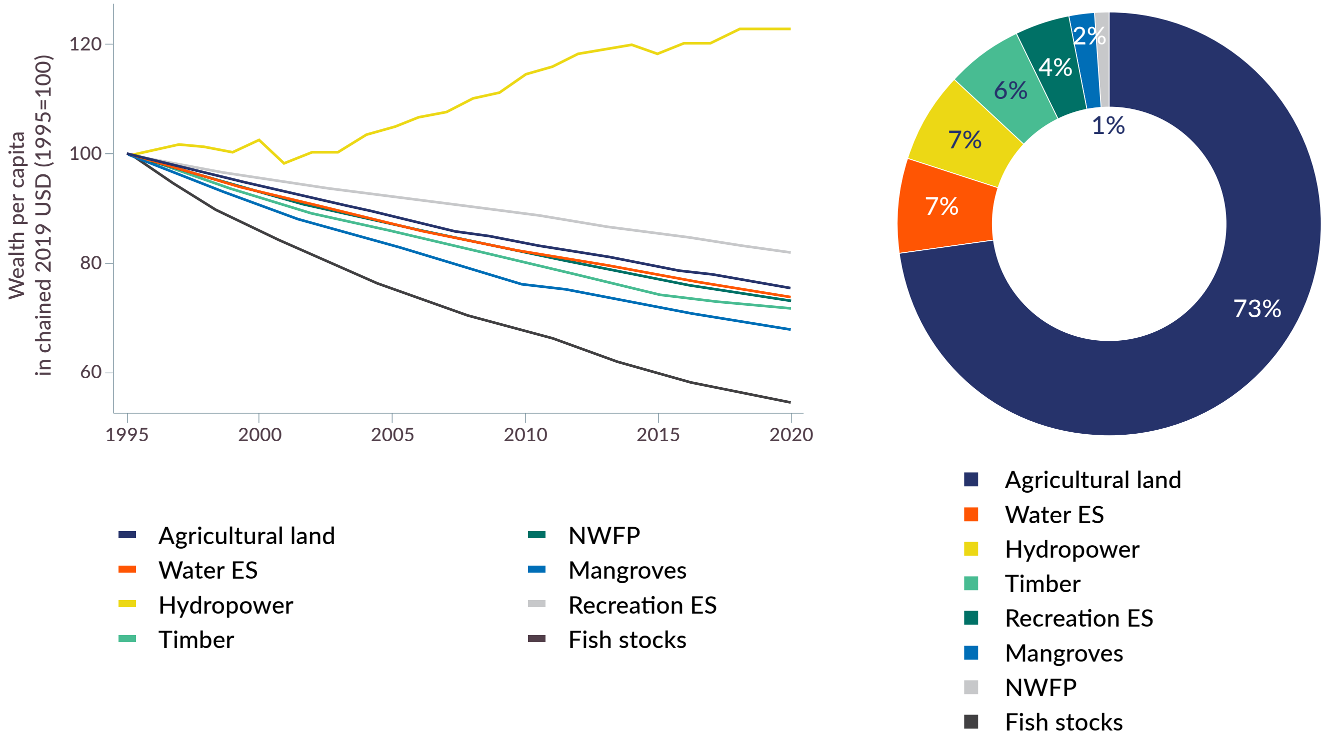
133 The non-wood forest ecosystem services included in CWON include water services (7 percent), recreation services (4 percent), and non-wood forest products (1 percent).

FIGURE 3.8

Renewable natural capital per capita, by asset, 1995–2020



Panel a: Trends in renewable natural capital per capita, by asset, 1995–2020 (1995=100)

Panel b: Nominal wealth shares for renewable natural capital, by asset, 2020

Source: World Bank staff estimates.

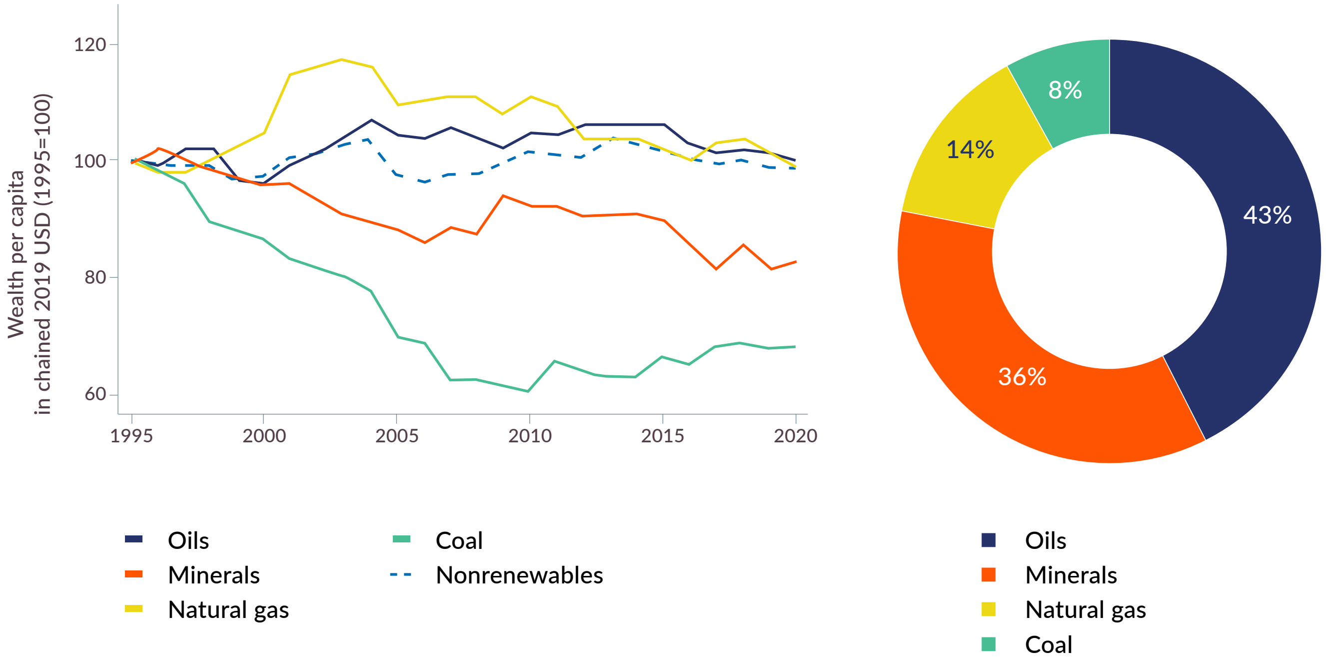
Note: Real wealth per capita for each asset is computed using the Törnqvist volume index. The relative volume changes use physical measurements of agricultural land (in square kilometers), timber (in hectares), mangroves (in hectares), non-wood forest ecosystem services (in square kilometers), hydropower (in GWh), and fish stocks (in tons). No weighting is used for measuring individual assets in real terms. The Törnqvist volume index for each asset is then chained with a base year of 2019 and the real value of each asset is computed using the nominal asset value for 2019. The global real value of each asset (measured in chained 2019 US dollars) is computed as the sum of real wealth for each asset divided by the global population. Changes in the real asset value per capita are reported relative to 1995 (set equal to 100). ES = ecosystem services. NWFP = non-wood forest products. Nominal wealth is measured in current US dollars and shares are reported in percent.

NONRENEWABLE NATURAL CAPITAL

In contrast to the large depletion trends observed for renewable natural capital, the world's nonrenewable natural capital—spanning oil, natural gas, coal, metals, and minerals—has been stable in per capita terms. Globally, nonrenewable natural capital per capita decreased by 2.5 percent between 1995 and 2020, with small increases in oil wealth offsetting declines in coal, natural gas, and minerals (Panel a, Figure 3.9). However, this trend was volatile, with periods of fast growth in the underlying asset base caused by discoveries and technological innovations followed by sudden declines in wealth driven by increased extraction. The low-carbon transition is likely to affect the nonrenewable natural capital wealth estimates in the short to medium term. However, large decreases in carbon-intensive fossil fuels (except for coal) have not yet been observed, as they still make up nearly 60 percent of the global value of nonrenewable natural capital (Panel b, Figure 3.9). The second-largest share (36 percent) is metals and minerals, with coal making up the remaining 8 percent.

FIGURE 3.9

Nonrenewable natural capital per capita, by asset, index to 1995, 1995–2020



Panel a: Nonrenewable natural capital per capita, by asset, 1995–2020 (1995=100)

Panel b: Shares in nominal wealth for nonrenewable natural capital, by asset, 2020

Source: World Bank staff estimates.

Note: Real nonrenewable natural capital per capita is measured in chained 2019 US dollars. For details on the computation of real wealth per capita per asset refer to the notes for Figure 3.7. The relative volume changes use physical measurements of oil (in barrels), gas (in terajoules), coal (in tons), and minerals (in tons). Nominal wealth is measured in current US dollars and shares are reported in percent.

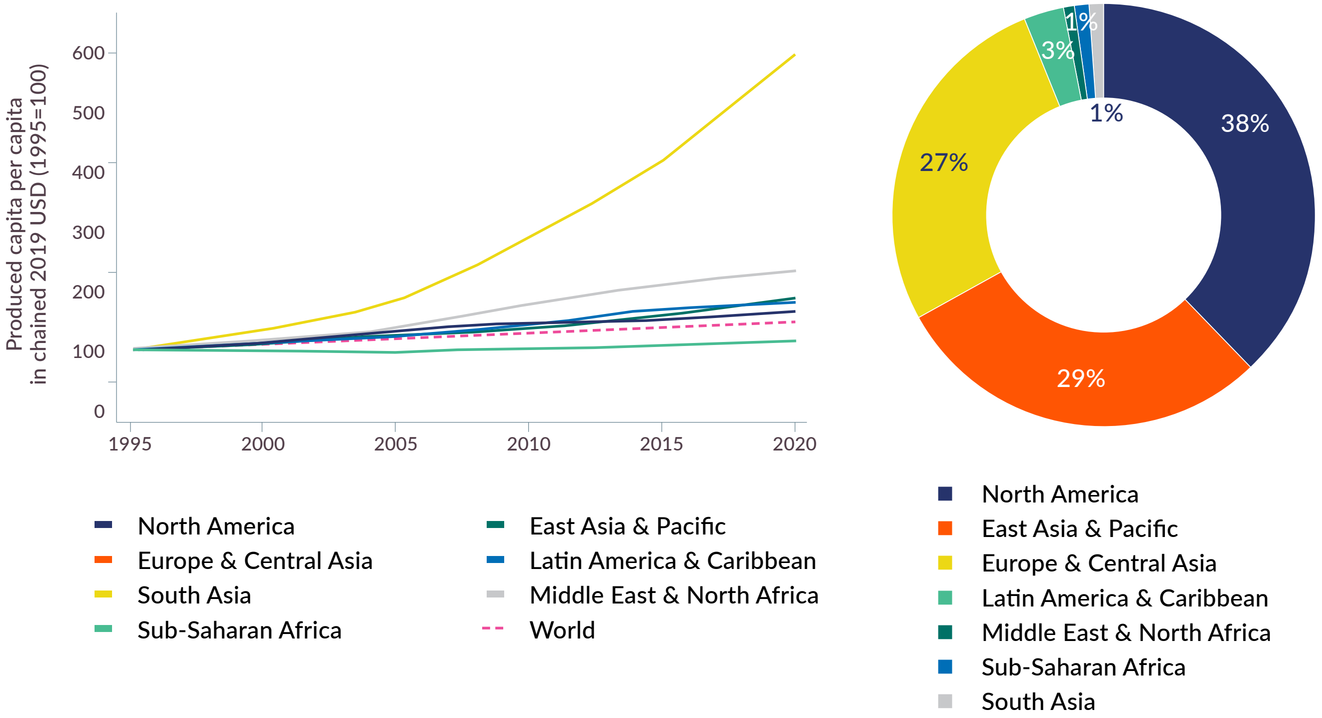
PRODUCED CAPITAL

Rapid urbanization and industrialization in high-income and emerging economies have produced substantial growth in produced capital wealth. On average, there is about 47 percent more produced capital per capita in the world than there was in 1995, and it has accumulated faster than population growth in all regions (Panel a, Figure 3.10). In 2020, most of the produced capital assets were concentrated in North America, Europe, and East Asia and the Pacific, which make up 94 percent of the global value (Panel b, Figure 3.10). Over the 1995–2020 period, they experienced steady growth rates, ranging from 48 to 89 percent.

However, the most substantial growth in produced capital per capita has been in emerging economies. Most notably, produced capital per capita in South Asia has increased by nearly 500 percent, albeit from a very low level. The region’s share in the nominal value of produced capital was merely 1 percent in 2020. Similar though less dramatic trends are observed in the Middle East and North Africa, with a 138 percent increase between 1995 and 2020. This increased the region’s share to 1 percent in the global value of produced capital. Sub-Saharan Africa, on the other hand, experienced the lowest growth rates on a per capita basis. Although the region made significant strides in accumulating produced capital wealth in real terms—matching that of other regions with a 129 percent increase over 25 years—rapid population growth led to a modest 17 percent increase in produced capital per capita from 1995 to 2020.

FIGURE 3.10

Produced capital per capita, by region, 1995–2020



Panel a: Trends in renewable natural capital per capita, by region, 1995–2020 (1995=100)

Panel b: Nominal wealth shares for renewable natural capital, by region, 2020

Source: World Bank staff estimates.

Note: Real produced capital per capita is measured in chained 2019 US dollars. For details on the computation of real wealth per capita for produced capital refer to the notes for Figure 3.7. For the relative volume changes, the following data are used: capital stock estimates from the Penn World Table 10.0 and urban land area estimates based on World Bank staff estimates using data from the United Nations Population Division's World Urbanization Prospects, the Food and Agriculture Organization (FAO), and the Center for International Earth Science Information Network. The weights are calculated using their nominal asset value relative to the nominal value of produced capital. Nominal wealth is measured in current US dollars and shares are reported in percent.

HUMAN CAPITAL

Human capital is a key component of wealth, constituting about 60 percent of the world's total nominal wealth value in 2020. It has grown consistently for the past 25 years due to increasing labor force participation and higher returns to education (Panel a, Figure 3.11). The share of human capital in total wealth generally increases as countries achieve higher levels of economic development. Human capital was greater than 60 percent of wealth in upper-middle-income and high-income countries in 2020, but only about 50 percent in low-income and lower-middle-income countries. Human capital is concentrated in the high- and upper-middle-income countries of North America (34 percent of the global value of human capital), Europe and Central Asia (27 percent), and East Asia and the Pacific (27 percent), as shown in Panel b of Figure 3.11. These regions have experienced modest growth rates, with, for example, 12 percent in North America and 16 percent in East Asia and the Pacific. In contrast, the Middle East and North Africa, and Latin America and the Caribbean regions show much larger increases of 82 percent and 62 percent, respectively, over the same period, albeit from a much lower starting point (their shares in the nominal value of human capital are 2 percent and 5 percent, respectively).

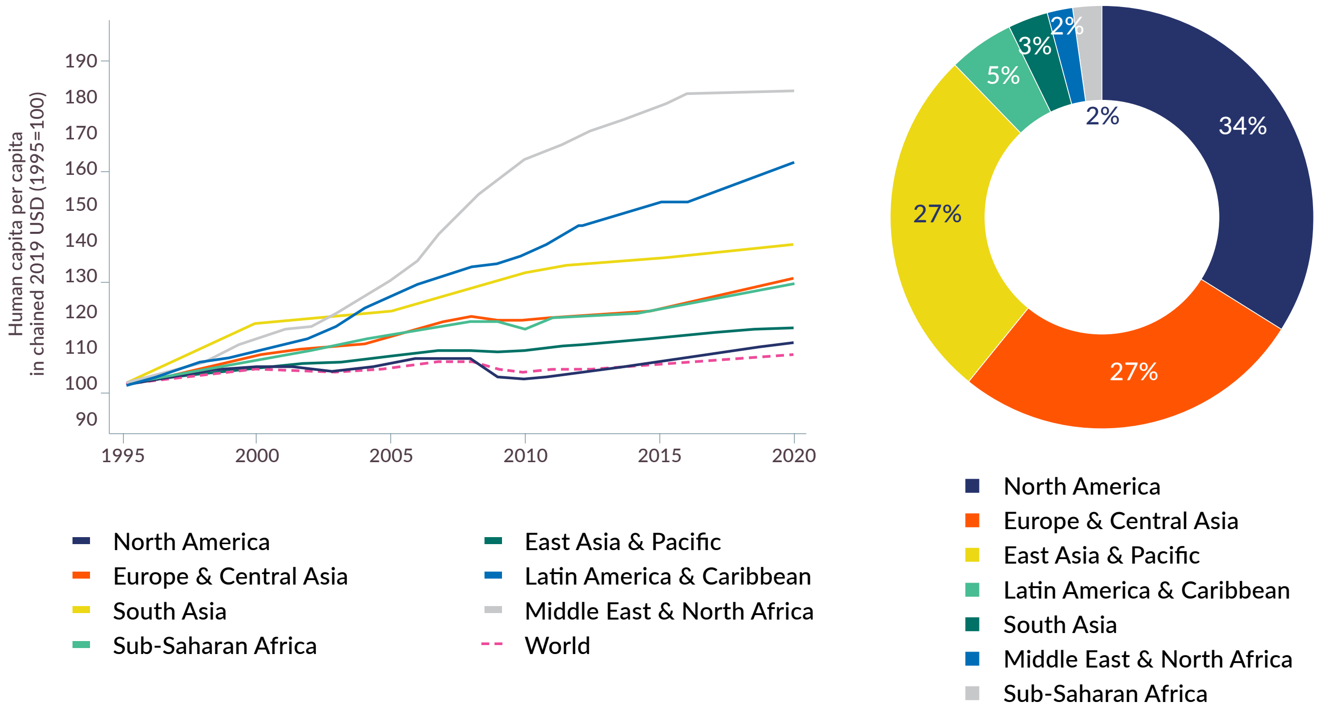
The human capital estimates reveal a significant disparity between the male and female shares of human capital. Little progress has been made toward greater gender parity in

FIGURE 3.11

Human capital per capita by region, 1995–2020

Panel a: Trends in human capital per capita, by region, 1995–2020 (1995=100)

Panel b: Nominal shares of human capital, by region, 2020



Source: World Bank staff estimates.

Note: Real human capital per capita is measured in chained 2019 US dollars. For details on the computation of real wealth per capita for human capital refer to the notes for Figure ES.4. For the relative volume changes, labor force numbers disaggregated by gender from the International Labor Organization (ILO) are used. These are scaled by the human capital index from the PWT to proxy for the average human capital per worker. The weights are calculated using their nominal asset value relative to the nominal value of human capital. Nominal wealth is measured in current US dollars and shares are reported in percent.

human capital over 1995–2020. Globally, women accounted for less than 40 percent of human capital in 2020 at all levels of human development (Panel a, Figure 3.12). The differences between regions are even more striking. For example, women accounted for only 15 percent of human capital in South Asia in 2020, while 44 percent of human capital was attributed to women in Latin America and the Caribbean (Panel b, Figure 3.12). 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 (World Bank 2023b).

TRENDS IN REAL WEALTH AND GDP PER CAPITA

GDP has long been used as a yardstick for progress, despite it not being well suited to assess long-term development prospects (Stiglitz, Sen, and Fitoussi 2010; Jorgenson 2018). In fact, GDP is a short-term measure of the market value of all final goods and services that are produced by a country in a given year. It is thus best suited to inform immediate fiscal and monetary policy questions. However, since it does not account for the costs of that production (for example, when capital is used up, degraded, or destroyed in the process of generating output), it fails to provide a comprehensive picture.[134]

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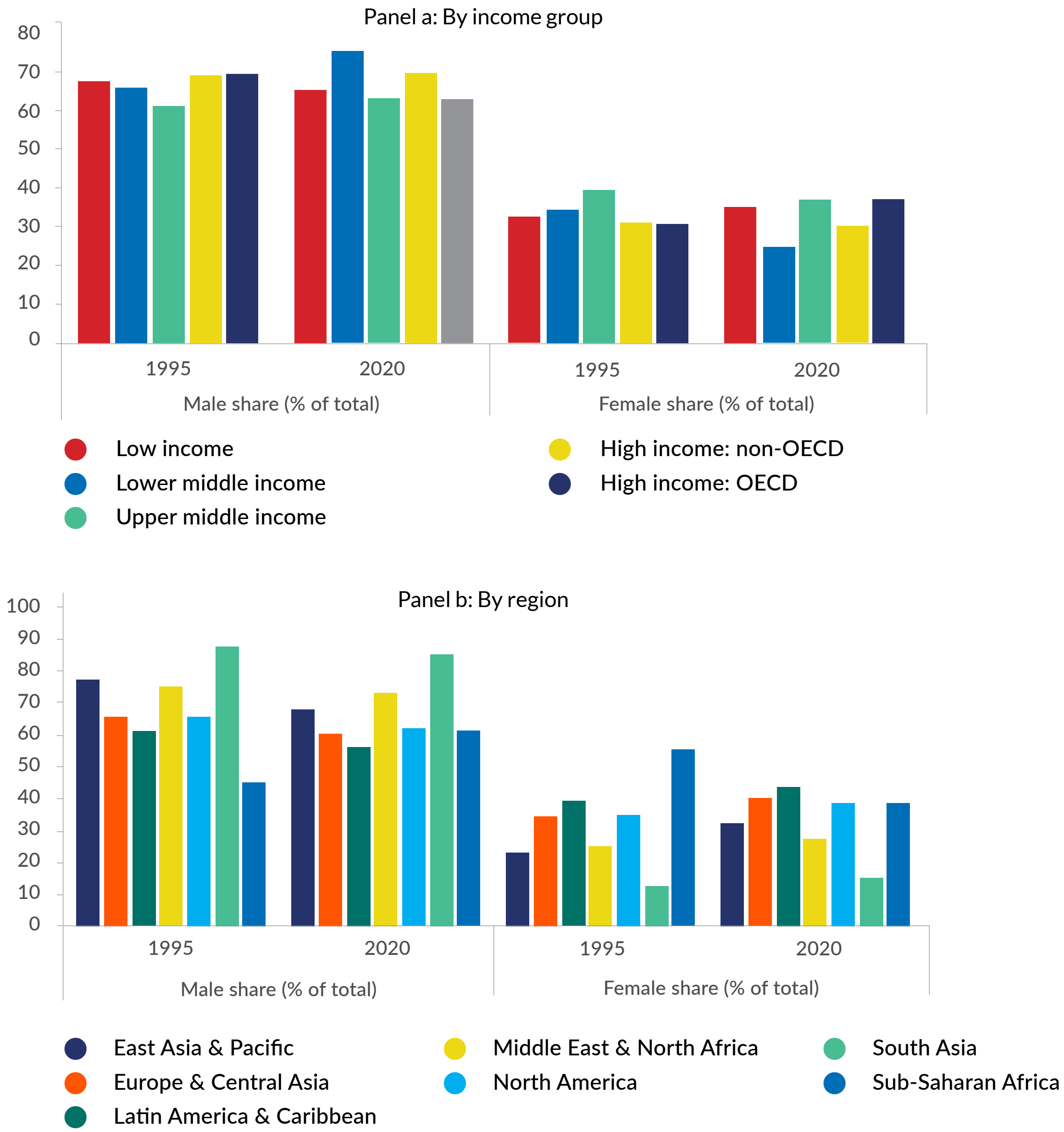
[134] Net domestic product (NDP), on the other hand, was explicitly designed to account for depletion of produced capital (SNA 2008, paragraphs 2.141 and 2.142). However, it does not account for the depletion and degradation of the other assets comprising wealth.

FIGURE 3.12

Shares of human capital by gender, 1995–2020



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

The measurement of GDP is also limited to produced capital and non-produced capital (such as natural resources, including land), and fails to account for new aspects of natural capital (such as new natural resources like renewable energy and ecosystem assets) and human capital. Whether progress is sustainable can instead be measured by how the future opportunities of a nation—as measured by its real comprehensive wealth per capita—are changing.

Wealth accounting captures the value of assets that are essential for long-term growth and helps monitor their accumulation and depletion over time. This report finds that real wealth per capita has increased by 21 percent between 1995 and 2020. This contrasts with the observed increase in real GDP per capita of about 50 percent over the same period (Figure 3.13). Changes in real wealth per capita are driven by changes in the real asset base and thus capture not only the accumulation of assets over time but also their depletion.

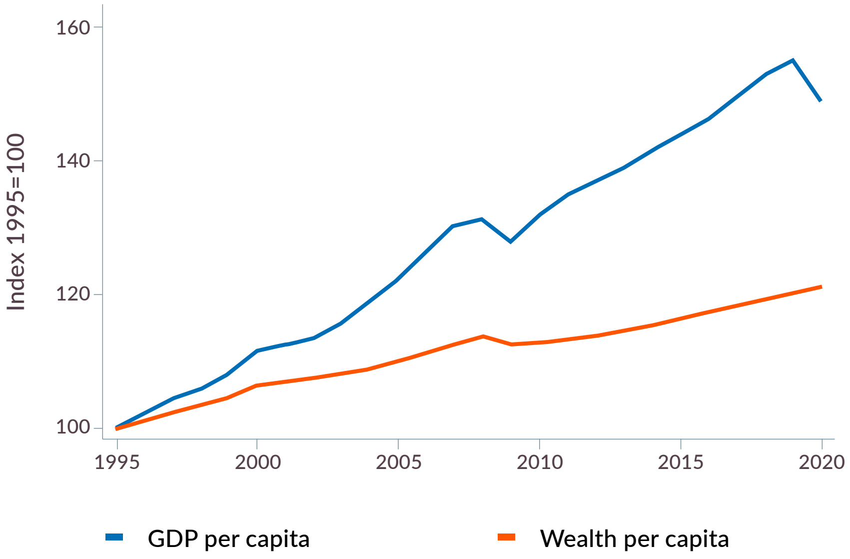
That is, real wealth per capita will decline as capital is used up, degraded, or destroyed in the process of generating output. Current GDP, on the other hand, often increases when asset depletion accelerates—for example, when a forest is clearcut and timber is sold. Moreover, wealth measures consider a more comprehensive set of productive assets than GDP, including additional natural resources like renewable energy and ecosystem assets. CWON provides researchers and analysts with the most comprehensive, transparent, and rigorous global data time series of the wealth of nations to conduct such analysis.

A more granular look at the data reveals that these global wealth trends mask large and persistent differences across income groups and FCV status. Rich countries are becoming wealthier, while poor and conflict-affected nations are in a downward spiral of low growth and wealth depletion. This is further illustrated in Figure 3.14, which maps changes in real GDP per capita to changes in real wealth per capita. While most countries are experiencing growth in both real GDP and wealth per capita, 15 percent of countries are experiencing positive GDP per capita growth rates while their real wealth per capita declines. For these countries, it will be critical to continue investing in building their asset base to ensure they can continue along a sustainable growth path. The rest of the countries either show declines in both GDP and real wealth per capita or did not experience growth in GDP per capita but appear to accumulate real wealth per capita.[135] These observed trends warrant a more detailed empirical analysis to explore what is driving these different trends. However, such an analysis goes beyond the scope of this report.

While the different asset components of wealth have been on starkly different trajectories, this has not yet acted as a brake on growth. Rising productivity and the ability to substitute one scarcer factor of production for a more abundant one offset the erosion of the asset base, most notably for renewable natural capital losses. It remains an open question how long this trend can continue considering that natural capital continues to be overexploited and is becoming scarcer. The extent to which limited substitutability could be accounted for within CWON through, for example, relative price adjustments or differentiated discount rates is further explored in chapter 4. Indicative estimates suggest that such adjustments would substantially increase the share of renewable natural capital in overall wealth.

FIGURE 3.13

Changes in global GDP and wealth per capita, indexed to 1995, 1995–2020



Source: World Bank staff estimates.
Note: GDP per capita is measured in constant 2015 US dollars from the World Bank's World Development Indicators database (NY.GDP.PCAP.KD), and wealth per capita is measured in chained 2019 US dollars.

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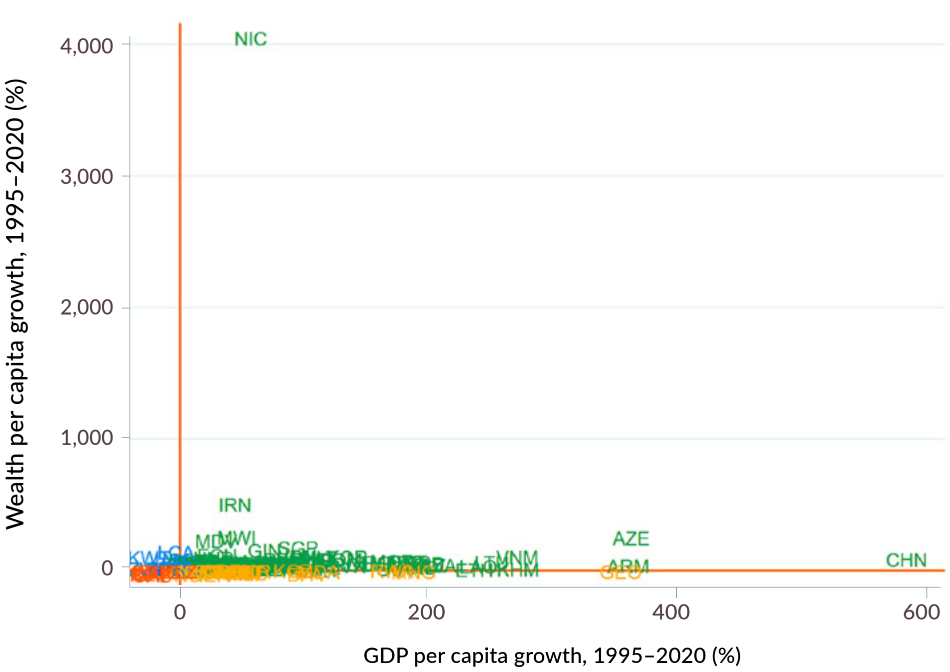
[135] This group of countries includes Jamaica, Kuwait, and St. Lucia.

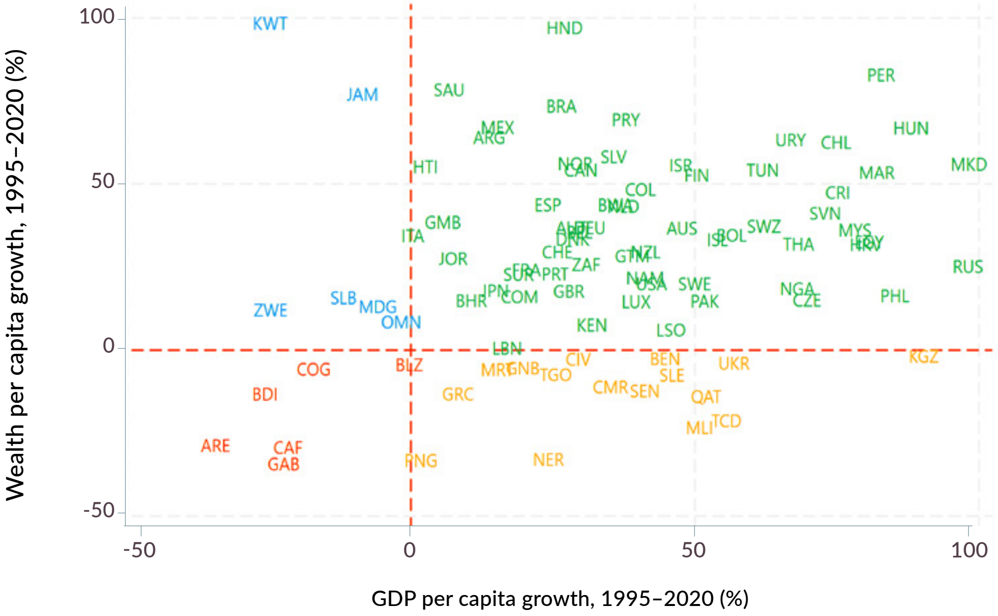
FIGURE 3.14

Cumulative GDP per capita growth vs. cumulative wealth per capita growth, 1995–2020

Panel a: Global sample



Panel b: Subsample with growth rates less than 100 percent



Source: World Bank staff estimates.

Note: GDP and wealth cumulative percentage growth between 1995 and 2020. The scatter plot shows country codes. Countries in green have increasing GDP and wealth per capita, countries in blue have declining GDP per capita but increasing wealth per capita, countries in orange have increasing GDP per capita but declining wealth per capita, countries in red have declining GDP and wealth per capita.

CONCLUSIONS

CWON's estimates of real comprehensive wealth per capita can be used to assess the sustainability of a nation's economic progress and provide complementary information to GDP. By producing these estimates, the World Bank addresses an important data gap, as all countries produce GDP, but few produce wealth estimates. As the world tackles multiple economic, environmental, and social crises, the UN Secretary-General has made "Beyond GDP" a priority. Wealth measures are an important step in that direction and can be used to assess sustainability trends across countries and over time, and provide critical information to support development planning. Importantly, with this new release, it is now possible to construct customized country-level wealth estimates, building on the CWON methodology. As part of the World Bank's reproducibility initiative, which independently verifies the reproducibility packages, the entire statistical code and input data[136] used to generate the nominal and real wealth estimates of the CWON database will be publicly released at http://www.worldbank.org/cwon. This unprecedented access will provide users with the opportunity to use more granular, country-level input data and modify assumptions as needed to support their own sustainability analysis.

CWON's long-term ambition is to support the analysis of sustainability. At this stage the extent to which this ambition has been fulfilled or even exceeded is an open analytical question. The analysis of sustainability is unavoidably constrained by how comprehensive the asset base is, that is, which assets are included on the CWON balance sheet and the precision with which they are measured (for a detailed discussion of these issues refer to chapter 1). The assets included on the CWON balance sheet have progressively expanded and the measurement has considerably improved over time. While it is important to acknowledge that important gaps in the coverage remain due to data and measurement constraints, the CWON balance sheet is nonetheless the most comprehensive wealth database available today in terms of coverage of assets, countries, and time series, aligned where possible with the internationally accepted statistical standards and guidelines in the SNA and SEEA. This alignment not only ensures methodological rigor, but also coherence with standard economic measures such as GDP.

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[136] For licensed data dummy datasets will be made available.

Annex A3: Measuring Wealth Using Purchasing Power Parities (PPPs)

The core wealth numbers compiled for this report are based on market exchange rates. That is, they do not control for price-level differences across countries, which can be significant, or market exchange rate fluctuations. There may be a case for compiling wealth estimates and components of wealth controlling for these price-level differences across countries by converting them into units of purchasing power parity (PPP terms). Indeed, for specific uses of the wealth data, including cross-country comparisons of specific asset groups, or comparisons with other economic statistics, data in PPP terms may be desirable.

The previous edition included a set of experimental estimates of nominal wealth in PPPs for 2018 (chapter 4 of World Bank 2021). The global benchmark PPP estimates were produced by the International Comparison Program, which is a worldwide statistical initiative led by the World Bank under the auspices of the United Nations Statistical Commission. It aims to provide comparable price and volume measures of GDP and its expenditure aggregates among countries within and across regions.

As part of this edition of CWON, further experimental estimates of total wealth and components of wealth have been developed in PPP terms for the entire time period (1995–2020), drawing on a new and expanded set of PPP estimates produced by the World Bank's DECDG team.[137] These estimates are still regarded as experimental because for PPPs to capture consumption possibilities stemming from asset values, each individual asset should have an asset-specific PPP factor (Inklaar et al. 2023). However, asset-specific PPP factors are not yet available. Given the importance of adjusting for purchasing power differences when analyzing the future consumption possibilities of a nation, the application of general consumption PPPs may be preferable to not controlling for price levels at all. These experimental estimates in PPP terms have been produced for the real terms volume-based wealth estimates (using the new volume index methodology) and for nominal wealth estimates (which are used to estimate the weights for assets within the overall volume index and can be used to assess shares of wealth). These estimates can be found in the published wealth accounts database on the World Bank data platform.

To illustrate the effect of the experimental PPP conversions, shares of global wealth (using the nominal wealth estimates) are shown in Figure A3.1, where the wealth gap between middle- and high-income countries is reduced considerably when controlling for price-level differences. The wealth shares for both lower- and upper-middle-income countries more than double. However, the wealth for low-income countries changes only marginally, further widening the wealth gap relative to the rest of the world.

Furthermore, an assessment was conducted to determine the extent to which controlling for price levels changes overall global trends. As general consumption-based PPP conversions do not vary across assets within a country, trends in real terms using the volume-based wealth index will be unaffected. However, levels of wealth will be affected, as wealth is shifted up or down to reflect differing purchasing powers of economies. Levels of wealth may be of interest in and of themselves, particularly when comparing wealth against other economic statistics. In addition, there will be changes to the trends of wealth and asset classes when they are aggregated across groups of countries, as the weights given to different countries within the group will change according to country PPP conversion factors.

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[137] DECDG stands for the Development Economics Vice-Presidency's Data Group. It hosts the International Comparison Program, which produces PPPs and comparable price-level indexes under the auspices of the UN Statistical Commission.

FIGURE A3.1

Global wealth shares, 2020


Panel a: In market exchange rate terms

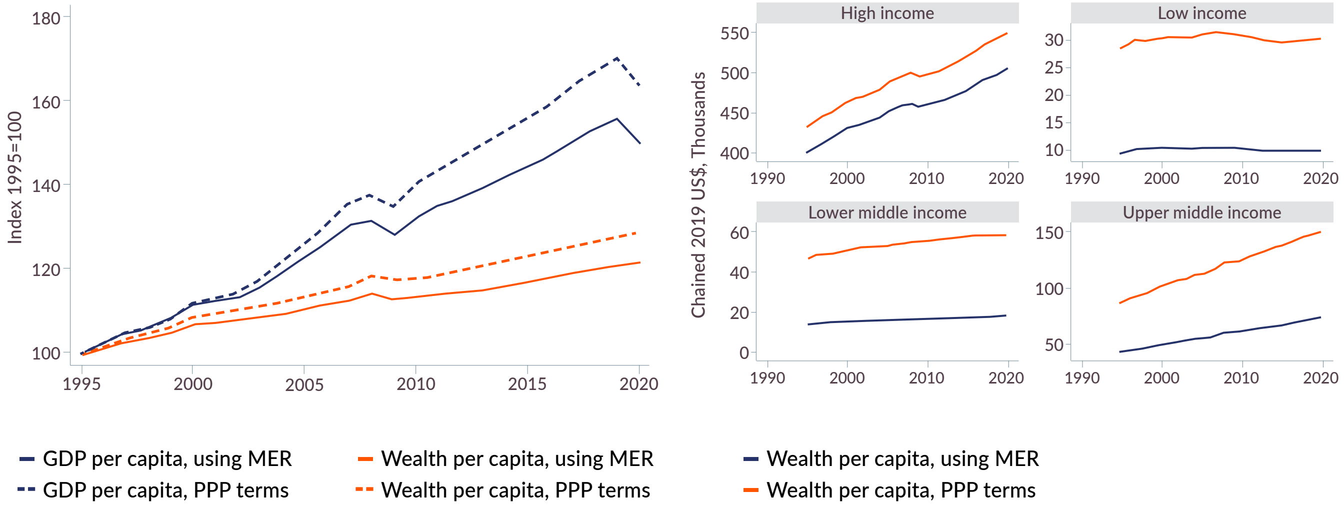
Panel b: In PPP terms

Source: World Bank staff estimates.

Note: Shares of global wealth are estimated using the nominal wealth estimates in current US dollars in PPP terms.

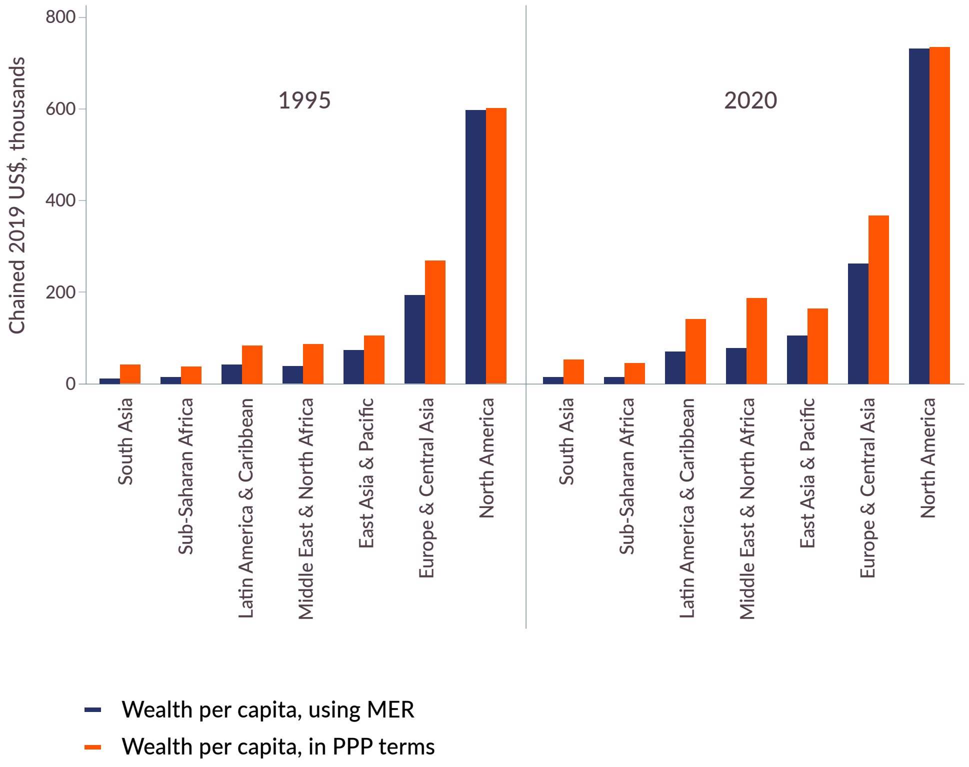
FIGURE A3.2

GDP and wealth trends per capita in market exchange rates and PPP terms


Panel a: World GDP and wealth per capita (indexed)

Panel b: Wealth per capita, market exchange rates and PPP terms, by income group

Panel c: Wealth per capita, PPP terms, by region



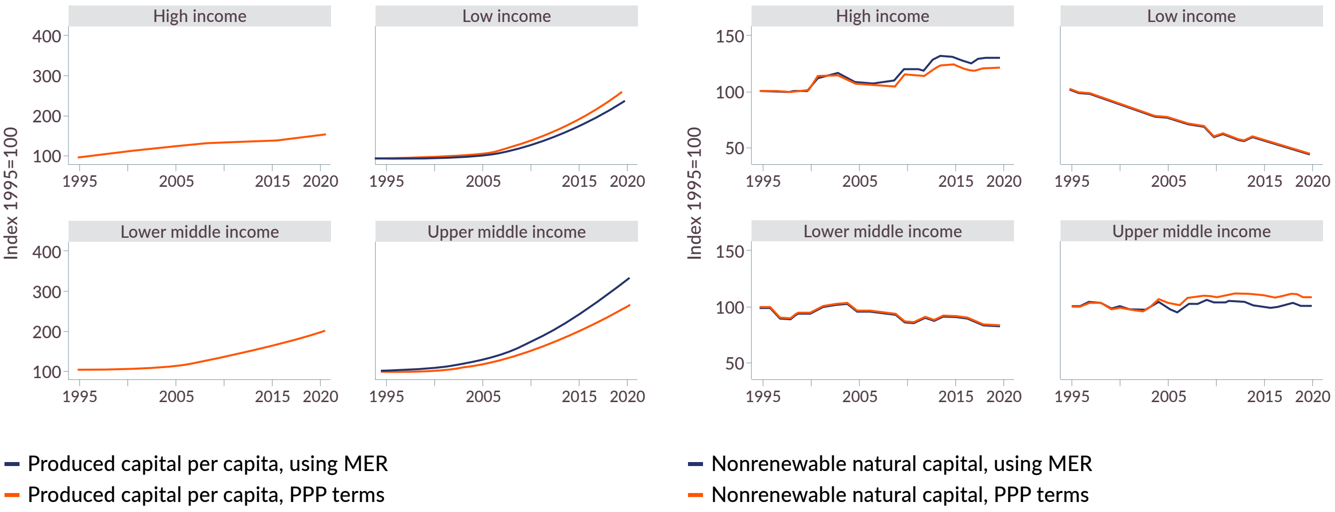
Source: World Bank staff estimates.
Note: The changes in wealth per capita are estimates in real terms using the volume index and are in chained 2019 US dollars in market exchange rates and PPP terms. Panel c estimates are total wealth figures all in chained 2019 US dollars in both market exchange rates and PPP terms.

Figure A3.2 provides insights into these effects. Panel a shows how trends in GDP per capita and wealth per capita are affected at a global level for market exchange rate and PPP terms measures. It shows how both GDP and wealth per capita have increased growth at the global level once purchasing power is adjusted for. This analysis has also shown that there are large effects for low- and middle-income countries, but trends are largely unaffected (Panel b). At a regional level, the shift to PPP also changes the ordering of the wealthiest regions in the world as of 2020. The Middle East and North Africa became richer than East Asia and the Pacific, while South Asia became richer than Sub-Saharan Africa in per capita terms.

Plotting the experimental PPP terms estimates using general consumption PPPs against market exchange rates corroborates that trends diverge once countries are aggregated by region or income group, but the overall growth and sustainability assessment has not changed (see Figure A3.3). This is important for the economics of sustainability, which is more generally concerned with long-term changes in wealth. For other uses of the wealth accounts, including comparisons with wider economic statistics, the large-level effects are notable across income groups and regions. Assuming future work may be able to use asset-specific PPP rates, further work would be required to assess whether these conclusions hold. Work on wealth accounting continues to evolve the production of statistical-grade wealth PPPs, and the interpretation of wealth accounts in PPP terms is an important area for further research.

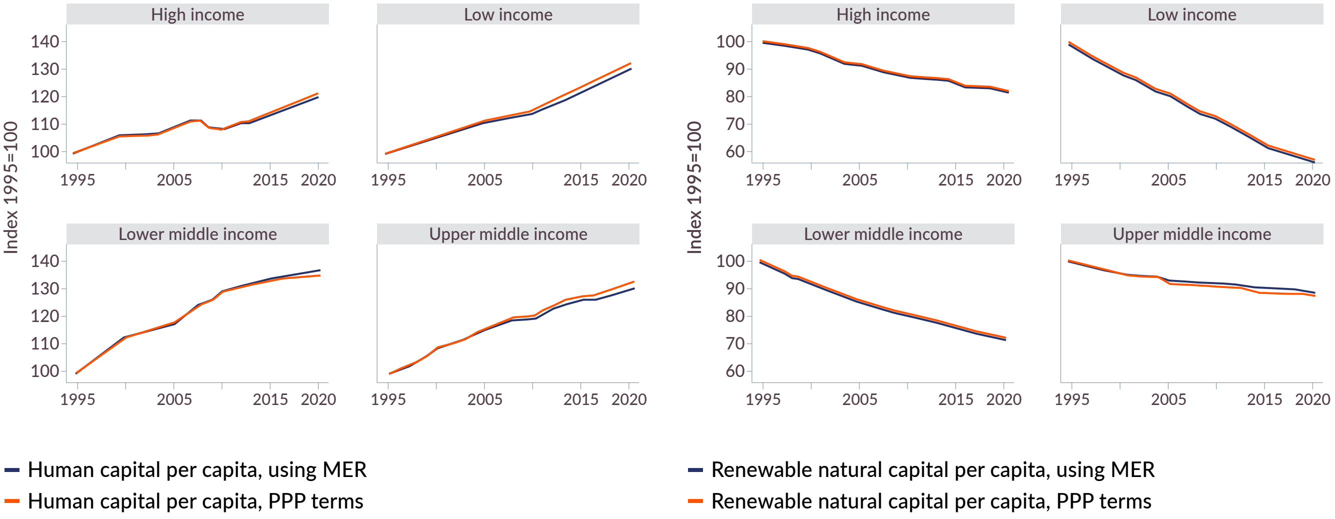
FIGURE A3.3

Trends in wealth asset classes in market exchange rates and in PPP terms, by income group



Panel a: Produced capital

Panel b: Nonrenewable natural capital



Panel c: Human capital

Panel d: Renewable natural capital

Source: World Bank staff estimates.

Note: The changes are in per capita terms using the real volume index and are in chained 2019 US dollars in market exchange rates and PPP terms indexed to 1995.

4 The Role of Limited Substitutability for Measuring Sustainability with CWON

MAIN MESSAGES

- The current CWON methodology implicitly assumes that all assets are highly substitutable. This means that a decline in, for example, natural capital can be compensated for through investments in other assets, such as produced or human capital. If overall wealth increases, development is considered weakly sustainable.
- This assumption is unlikely to hold in the current context, where natural resources are in limited supply and experience widespread overexploitation and degradation. The degree of substitutability will likely vary as natural resources become scarcer and reach critical levels due to climate change, biodiversity loss, tipping points, and the crossing of planetary boundaries.
- It is thus necessary to adjust standard economic models for limited substitutability between natural capital and other assets. Simulations show that natural capital decline can have considerable implications for a country's growth potential as well as its resilience and fragility to natural shocks.
- Limited substitutability can also be introduced into wealth accounting either via differentiated discount rates or relative price adjustments. Indicative estimates suggest that such adjustments substantially increase the share of renewable natural capital in overall wealth. However, implementation is hampered by limited empirical evidence, and more research is needed to determine the best approach for CWON.

INTRODUCTION

Measuring whether a country is growing sustainably remains an unresolved problem in environmental economics. Typically, sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, paragraph 27; see also Pezzey 1992). This implies that one condition for development to be sustainable is that the aggregate per capita value of wealth should not decline over time (Hartwick 1978; Hamilton and Clemens 1999). A key assumption is that natural capital and other forms of capital can be substituted for each other relatively easily and that perfect complementarity can be ruled out.[138] As a result, investment in any form of capital contributes to welfare, since a decline in, say, natural capital can be compensated for through investments in, for example, produced or human capital. If overall wealth increases, development is thus considered to be weakly sustainable.

However, it seems unlikely that a high degree of substitution among assets can continue in a world where natural resources, such as land, are in limited supply and experience widespread overexploitation and degradation (Cohen et al. 2019; Drupp and Hänsel 2021; Rad et al. 2021). The degree of substitutability will thus likely vary as natural resources become scarcer and reach critical levels due to climate change, biodiversity loss, tipping points, and the crossing of planetary boundaries. With poor substitution, depletion of resources and threats of critical scarcity or tipping points would translate into giving a considerably higher weight—typically through a shadow price (Dasgupta 2009)—for the depletion of natural capital.

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[138] CWON allows for perfect substitutability as well as low degrees of substitutability. That is, one type of capital can replace another and keep total wealth constant. As one of the assets becomes scarcer, substitution might still be possible, but prices will adjust in favor of the scarce good.

Moreover, limited substitutability of factors of production has significant implications for the growth potential of an economy and its resilience to natural shocks. For example, Smulders and van Soest (2023) show that with limited substitutability of factors of production, economic growth is ultimately determined by the slowest-growing factor. Limited substitutability between natural assets and other factors of production, such as labor, can also shape economic resilience against natural shocks. Karayalcin and Onder (2023) show that the magnitude of the original impact (fragility) and the speed of the subsequent recovery (resilience) are determined by the ability of the economy to reallocate inputs between sectors. This ability will in turn be driven by the inputs' degree of substitutability as well as institutional characteristics, such as economic openness and property rights over natural assets.

Two key challenges of introducing limited substitutability in the context of CWON are determining the appropriate shadow price of natural capital (which would require adjusting the market prices currently being used) and estimating the elasticity of substitution both across and within asset categories. From a theoretical point of view, shadow prices for sustainability accounting reflect the contribution of capital goods to sustainable welfare when used in combination with other assets in the future. As a result, they reflect whether different capital stocks are good substitutes or not, and whether capital is used efficiently or not (that is, how externalities, suboptimal resource management, and other second-best issues play a role).

From a practical point of view, translating market and imputed prices to shadow prices requires adjustments along these lines. On the one hand, both market prices and imputed values of non-marketed goods need to be adjusted to account for market imperfections (Dasgupta 2001). On the other hand, the value of shadow prices will depend on the extent to which the various capital stocks are complements or substitutes in production (Cohen et al. 2019). When inputs are substitutes in production, the shadow price of scarce natural capital inputs will be higher, and the degree of substitutability lower (Smulders and van Soest 2023), requiring further adjustments to the market prices.

Conventional approaches to tracking whether an economy is on a sustainable trajectory, such as country-level natural capital accounting initiatives or the CWON work program, are based on the weak sustainability framework, using observed market prices where possible. The main challenge is how to extend the framework to account for limited substitutability by adjusting shadow prices (for example, Smulders 2012). The theory on discounting and non-market valuation, for instance, suggests either using differentiated discount rates or relative (shadow) price adjustments (Weikard and Zhu 2005; Hoel and Sterner 2007; Traeger 2011; Gollier 2010; Baumgärtner et al. 2015; and Drupp 2018). To date, there is limited empirical evidence to guide the implementation of either approach.

This chapter explains why the existing weak sustainability framework is not appropriate today and discusses how limited substitutability can affect both the growth and resilience of an economy to natural shocks. Next, indicative wealth estimates using both differentiated discount rates and relative price adjustments are presented, primarily to demonstrate why these would be important adjustments. However, further research is needed to find the most suitable approach to integrate limited substitutability in a systematic way in the CWON estimates, which will be further discussed in the conclusion.

WHY A WEAK SUSTAINABILITY FRAMEWORK IS NOT APPROPRIATE TODAY

Concerns about the depletion of natural resources occur with remarkable frequency. Malthus famously opined that the limited availability of land would lead to mass starvation. Likewise, Jevons (1865) warned about the risks of running out of coal as an energy resource, and the Club of Rome's *Limits to Growth* report projected widespread shortages for a host of minerals that have yet to materialize (Meadows 1972). Market forces, combined with rising productivity and the ability to substitute one scarcer factor of production for a more abundant one, has meant that such pessimism has been unwarranted. This is why weak sustainability is based on the premise that an economy is sustainable so long as there is non-declining welfare over time, irrespective of the fate of individual resources.

An implicit assumption in the weak sustainability paradigm is that there are no scarce resources that are essential to life or economic activity. If there is a resource of a certain quality that is critical, such as water or air, this would imply that there is an absolute limit to substitution between the critical asset and other assets. When an asset renders a service that is essential and irreplaceable, then losing that asset would entail much greater loss of welfare than losing a readily replaceable one. A clear implication is that the close substitutability assumption would be inappropriate in such cases. As shown formally by Baumgärtner et al. (2015), as natural resource scarcity increases, the willingness to substitute these for other human-made assets also diminishes. Though of less existential concern, the preferences of consumers also determine substitutability between commodities and, hence, whether welfare is continuously increasing as stocks of an asset or its services decline.

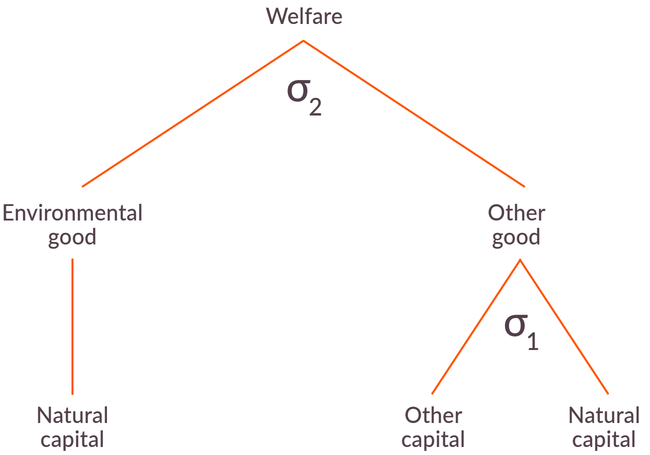
Scientific evidence suggests that the world has transgressed (or is at risk of transgressing) several planetary boundaries that are deemed critical for sustaining life and economic activity (Richardson et al. 2023). The update of the planetary boundaries framework finds that six of the nine boundaries are transgressed, suggesting that Earth is now well outside of the safe operating space for humanity. A key indicator of biosphere functioning that drives the Earth system—net primary production—has also been transgressed (Richardson et al. 2023). In such contexts, the assumption of high substitutability between critical natural assets and human-produced assets seems both misleading and inappropriate.

THE IMPORTANCE OF CONSIDERING LIMITED SUBSTITUTABILITY FOR ECONOMIC GROWTH

While the problem of imperfect substitutability is often recognized, the theoretical consequences and the implications for measuring sustainability remain at the frontiers of cutting-edge research. Smulders and van Soest (2023) make an important contribution to our understanding of how shadow prices may alter with limited substitutability. The paper considers a second-best world in which both market prices and imputed prices for non-marketed goods do not reflect their true shadow prices. The study considers a rich set of possibilities with imperfect substitutability along a production hierarchy (σ_1), as shown in Figure 4.1, as well as imperfect substitutability in consumption (σ_2). The authors derive solutions for these cases in a world of second-best prices and show that with limited substitutability, shadow prices for natural capital are higher. In addition, the difference between imputed prices and actual shadow prices increases as substitutability decreases.

FIGURE 4.1

A framework for introducing limited substitutability in production and consumption



Source: Smulders and van Soest 2023.
Note: σ_1 is the elasticity of substitution in production between natural and other capital. σ_2 is the elasticity of substitution in consumption between the environmental and other (produced) goods.

Moreover, limited substitutability in both production and consumption is relevant in determining the sustainability of economic growth. In Figure 4.1, if natural capital is growing slowly, and is a close enough substitute to produced capital, then the scarcity of natural capital will not impede sustainable growth, as long as produced capital increases sufficiently. Conversely, where there is limited substitutability between natural capital and other forms of capital, the scarcity of natural capital would impede economic growth. An important finding of the paper is that with poor substitution, growth is ultimately determined by the factor that is in relatively short supply.

THE IMPORTANCE OF CONSIDERING LIMITED SUBSTITUTABILITY FOR ECONOMIC RESILIENCE IN DEVELOPING ECONOMIES

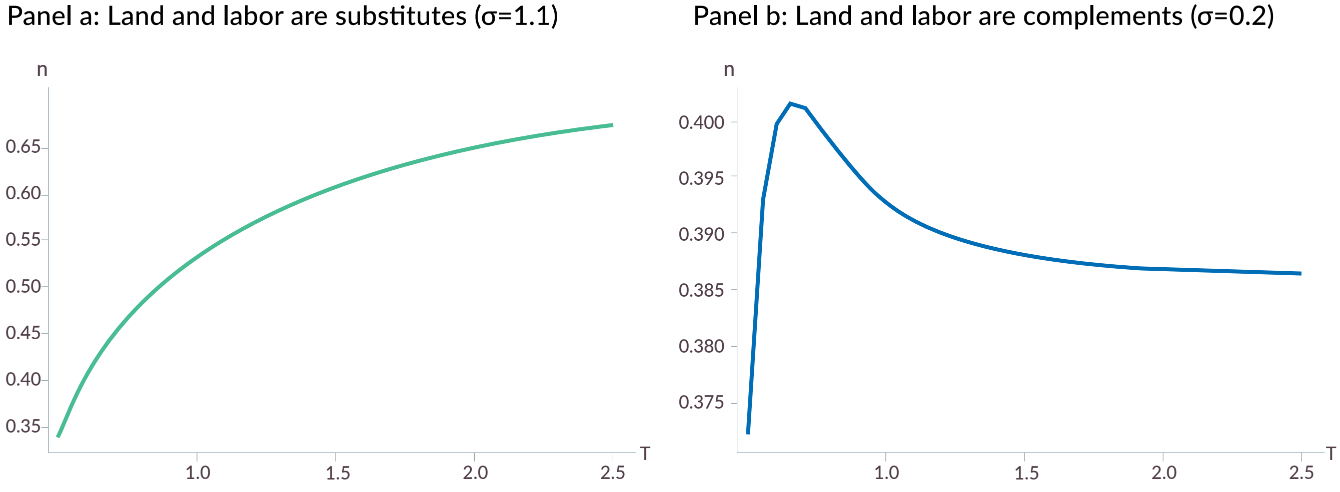
Limited substitutability between natural assets and other factors of production, such as labor, can also shape economic resilience to natural shocks. In this regard, Karayalcin and Onder (2023) explore two main aspects: (i) how natural shocks are propagated by economic mechanisms—in this case, through the reallocation of labor between sectors; and (ii) how institutional characteristics of the economy, such as economic openness and property rights over natural assets, can shape such propagation. To address these points, the paper employs a structural transformation (general equilibrium) model. In this model, one sector (agriculture) uses a nature-based asset (land) in conjunction with labor, while the other sector (manufacturing) uses labor exclusively for simplicity, to derive significant conclusions.

Consider the economic propagation of a natural shock in a closed economy with incomplete property rights over natural assets. A decrease in land (T) influences labor allocation between sectors through three channels. First, it diminishes labor productivity in agriculture. With perfect labor mobility between sectors, this effect would prompt labor to move to manufacturing, where wages are higher. Second, it reduces the supply of food, leading to an increase in the relative price of food and wages (as the closed economy cannot import it). This factor limits the labor outflow from agriculture. Third, under a plausible assumption that poorer people allocate a greater share of their expenditure to food,[139] the land shock boosts the relative demand for food, reinforcing the second channel.

Figure 4.2 illustrates that when land and labor are highly substitutable (Panel a), the second and third channels dominate, and a decrease in land draws labor from manufacturing into agriculture in net terms. Conversely, when the substitutability is low—that is, when land and labor are complements in agriculture—the first channel dominates, and a decrease in land pushes labor out of agriculture due to lower labor productivity and, hence, wages. The only exception in this scenario is when the land is already too small to begin with, in which case labor is still drawn into agriculture after the shock. This dependence of labor flows on the asset stock, in this stylized model, land, provides an additional argument in favor of better measuring the non-marketed wealth in an economy.

FIGURE 4.2

Manufacturing employment by land and elasticity of land-labor substitution



Panel a: Land and labor are substitutes (σ=1.1)

Panel b: Land and labor are complements (σ=0.2)

Source: Karayalcin and Onder 2023.

Note: n is the fraction of labor employed in manufacturing, T is the endowment of land, and σ is the elasticity of substitution between land and labor.

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[139] This assumes that consumers have non-homothetic preferences, which is a standard assumption in economic theory.

Next, consider how these responses and the degree of substitutability drive economic resilience in developing countries. According to the model of Karayalcin and Onder (2023), economic resilience (the ability to recover from a shock quickly) is determined by how swiftly natural assets can regenerate after a shock. The speed of such growth is in turn determined by two factors: (i) the stock of land: regeneration speed is higher when the stock is low;[140] and (ii) harvesting: the more labor is allocated to agriculture, the slower the regeneration. The elasticity of substitution between land and labor influences both factors and, in turn, an economy's economic resilience to the natural shock. In comparison to the case with low elasticity of substitution (complements), the case with high elasticity of substitution (substitutes) has important differences:

- The economy has a higher equilibrium land stock. Therefore, other things being equal, when an (identical) natural shock reduces the land, land tends to recover faster.
- The economy allocates more labor to agriculture after a shock, as explained above. Consequently, other things being equal, land tends to recover slower.

In simulations, the former effect tends to dominate, resulting in faster land recovery after a shock when it is easily substitutable with labor. Therefore, among otherwise identical economies, the one with higher land-labor substitutability tends to be more resilient. Nonetheless, the downside is that the same economy tends to be more fragile against natural shocks. With a larger nature-sensitive sector that comes with more labor allocation to agriculture, natural shocks can lead to a more drastic reduction in GDP at the time of impact.

Both theoretical models suggest that it is vital to seek empirical estimates of the degrees of substitutability of key assets in both the production and utility spaces to identify where obstacles to sustainability may begin to emerge. Such estimates can help quantify the economic impacts discussed.

PRACTICAL APPROACHES TO ACCOUNT FOR LIMITED SUBSTITUTABILITY

Supporting any efforts to account for limited substitutability in natural capital and wealth accounting initiatives would also require empirical estimates to adjust shadow prices. However, such evidence is often scarce (for examples, see Drupp 2018; Cohen et al. 2019; Rouhi Rad et al. 2021; Drupp et al. 2023a, b). Most government appraisal and environmental-economic accounting guidance thus has yet to explicitly address limited substitutability of non-market goods (Groom et al. 2022). However, two approaches for dealing with this empirical challenge can be applied in the context of environmental-economic or wealth accounting (Weikard and Zhu 2005; Hoel and Sterner 2007; Traeger 2011; Gollier 2010; Baumgärtner et al. 2015; Drupp 2018): differentiated discount rates or relative price adjustments.

Differentiated discount rates: This approach uses a lower discount rate for non-market goods and services, such as for ecosystem services derived from natural capital, than for manufactured goods to reflect their increasing scarcity and limited substitutability. For example, guidelines by the Asian Development Bank, Australia, and Canada suggest using lower discount rates for environmental goods or non-market benefits (6 percent, 4 percent, and 3 percent, respectively; Groom et al. 2022).[141] By contrast, CWON applies a uniform discount rate of 4 percent as was done in previous CWON reports (following World Bank 2006). This is twice as high as the recently adopted rate of 2 percent in revised guidelines in the United States (OMB 2023), which is also the real social discount rate that receives most support according to expert recommendations (Drupp et al. 2018; Nesje et al. 2022).

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[140] This is a common assumption in environmental economics, which assumes that the regeneration speed diminishes as the stock increases.

[141] Some countries also allow the discount rate to vary over time. For example, the UK Treasury's Green Book proposes a 3.5 percent rate, which declines to 3 percent after 30 years. See https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020.

Relative price adjustments: This approach explicitly considers how relative prices of non-market goods change over time compared to market traded consumption goods. Comprehensive consumption equivalents are then computed for each point in time and a single discount rate is used to compute future comprehensive consumption equivalents. However, since country-specific estimates are scarce,[142] global-level estimates of relative price changes are typically used to inform governmental policy guidance (Groom and Hepburn 2017). For instance, the Netherlands's discounting guidance recommends using a relative price change of 1 percent per year, while the UK's Department for Environment, Food and Rural Affairs "uplifts" the damage costs of air pollution by 2 percent per year (Groom et al. 2022).

For imperfect complements, both approaches are mathematically equivalent and related in a simple formula within the standard constant-elasticity-of-substitution framework (see Drupp et al. 2023b):

Relative price change=$r_C - r_E = \frac{1}{\sigma_2}(g_C - g_E)$

Where r_C is the discount rate for market goods, r_E is the discount rate for non-market ecosystem services derived from natural capital, σ_2 is the constant-elasticity-of-substitution (see Figure 4.1), and g_C and g_E are the respective (forecasted) growth rates.

To illustrate how accounting for limited substitutability would affect the CWON wealth estimates, indicative estimates using both approaches were produced. For the limited substitutability approach using differentiated discount rates, a 2 percent discount rate is applied to renewable natural capital in line with the latest recommendation of leading experts, adjusted for relative growth rates (Drupp et al. 2023a), while all other assets are discounted at the previous 4 percent discount rate. This captures the real income effect according to which future asset values are increasing in real monetary terms due to increasing real incomes, using a forecasted growth rate of GDP per capita of around 2 percent per year (Christensen et al. 2018; Müller et al. 2022). When natural capital is declining, the discount rate of the relative price change adjustment should additionally consider a real scarcity effect, and further subtract the rate of decline from the 2 percent rate. For relative price changes, Drupp et al. (2023b) have generated experimental estimates of non-wood forest ecosystem services adjusted for relative price changes, where forest area has been declining globally by around 0.1 percent per year.

INDICATIVE ESTIMATES FOR COMPREHENSIVE WEALTH USING DIFFERENTIATED DISCOUNT RATES

Applying differentiated discount rates—using a 2 percent discount rate for all renewable natural capital assets adjusted for relative growth rates and a 4 percent discount rate for all other assets—has significant impacts on the CWON real wealth estimates. As the net present value of renewable natural capital is computed over a 100-year time span, lowering the discount rate effectively means that future streams of benefits are given more weight, increasing the value of renewable natural capital wealth. The share of renewable natural capital in global wealth thus doubles relative to the main estimates that use a uniform discount rate, increasing by 5 percentage points in 1995 and 6 percentage points in 2020 (Figure 4.3).

Using a lower discount rate also leads to a more substantial decline in renewable natural capital per capita, which in turn depresses growth in real wealth per capita. Renewable natural capital per capita declines by 4 percentage points more relative to when a uniform discount rate is used, while growth in global wealth per capita falls from 21.4 percent in 1995 to 17.7 percent in 2020 (Figure 4.4). The gap between the two wealth estimates also widens over time as natural resource degradation across the world accelerates.

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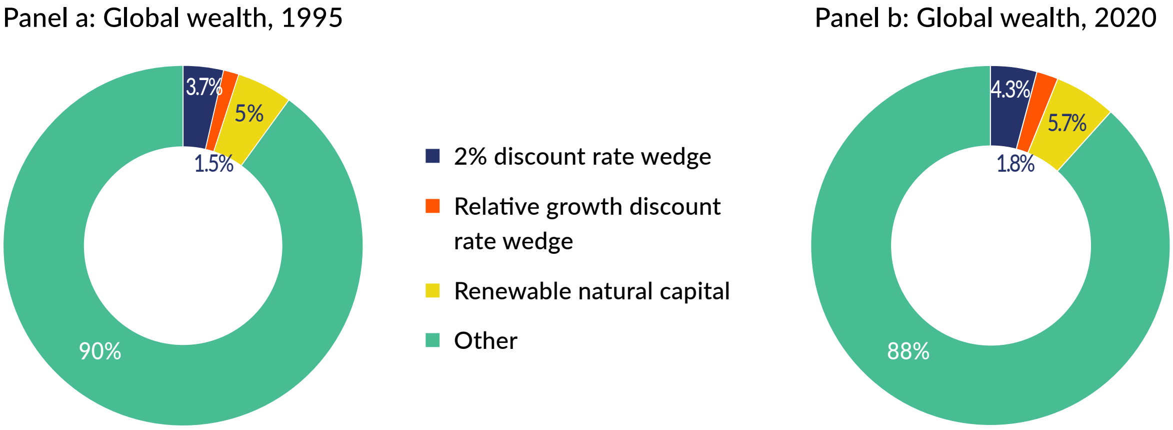
[142] Baumgärtner et al. (2015) were the first to estimate relative price changes at the global level, assuming that the elasticity of substitution is constant across all countries and ecosystem service types. Subsequently, they applied national growth rates to arrive at country-level results. Heckenhahn and Drupp (2022) provided the first comprehensive country-specific evidence, estimating growth rates of 15 ecosystem services and the degree of limited substitutability based on a meta-analysis of 36 German willingness-to-pay studies.

FIGURE 4.3

Distribution of global wealth using differentiated discount rates, 1995 and 2020

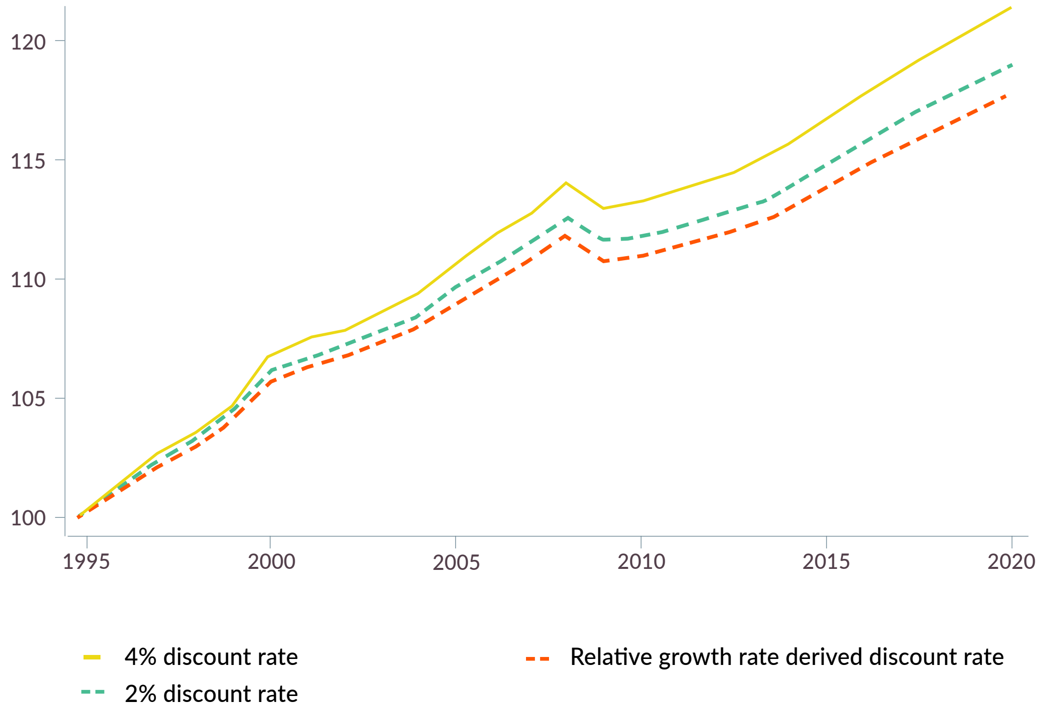


Source: World Bank staff estimates.

Notes: Wealth is measured in current US dollars.

FIGURE 4.4

Trends in wealth per capita using differentiated discount rates, indexed to 1995, 1995, and 2020



Source: World Bank staff estimates.

Note: Wealth per capita is measured in chained 2019 US dollars.

Differentiated discount rates clearly have a substantial impact on the real wealth estimates reported in CWON. More research is needed to determine to what extent the assumption of a uniform discount rate should be modified. If a decision is made to change the discount rate, more research is needed to determine whether the discount rate should vary across assets, countries, and potentially even over time.

INDICATIVE ESTIMATES FOR NON-WOOD FOREST ECOSYSTEM SERVICES USING RELATIVE PRICE ADJUSTMENTS

The second set of experimental estimates aims to illustrate how relative price adjustments affect value estimates for renewable natural capital using non-wood forest ecosystem services as a case study. This work was carried out by Drupp et al. (2023b), who have developed the first systematic global empirical evidence base to inform relative price adjustments of ecosystem services. In this context, relative price changes are measured as the relative change in the valuation of ecosystem services (Hoel and Sterner 2007). This will be driven by both their degree of substitutability and changes in their relative scarcity over time, which need to be estimated separately.

The first step is to estimate the elasticity of substitution, which Drupp et al. (2023b) estimate indirectly using the inverse of the income elasticity of the willingness to pay (WTP) for ecosystem services (Ebert 2003). In fact, there is a large literature on estimating WTPs, where respondents are typically asked how much they value a given ecosystem service or—put differently—what is the maximum price they would be willing to pay for it. These WTP estimates thus depend on the survey context, as well as the respondent's characteristics, such as income, which Drupp et al. (2023b) collect through a systematic review (meta-analysis) of the WTP literature.[143] This information is then used to estimate the income elasticities of the WTP for ecosystem services,[144] and subsequently, the elasticity of substitution between ecosystem services and human-made goods (cf. Heckenhahn and Drupp 2022).

Their main estimate of the elasticity of substitution suggests a weak degree of substitutability between ecosystem services and human-made goods, with an elasticity of substitution of 1.3 (an elasticity greater than one implies substitutability, while an elasticity less than one implies complementarity). They also find that the degree of substitutability varies across types of ecosystem services (Table 4.1). It is highest for rivalrous ecosystem services, such as recreation and ecotourism—that is, activities for which alternatives exist. On the other hand, the elasticity is lowest for forest ecosystem services that cannot be substituted easily, such as water regulation. For example, Damania et al. (2023) find that there are complementarities between human health and hydrological services provided by forests (Box 4.1). Most 95 percent confidence intervals border or overlap Cobb-Douglas substitutability (an elasticity of unity). Thus, while all cases yield mean estimates in the substitutes domain, it cannot be excluded that ecosystem services may be regarded as complements.

The second step in the analysis is to proxy for the global shift in the relative scarcity of ecosystem services. These can either be estimated using a historical time series of good-specific growth rates (following Baumgärtner et al. 2015 or Heckenhahn and Drupp 2022) or derived endogenously as part of a global integrated climate-economy assessment model (for example, Drupp and Hänsel 2021). Following Baumgärtner et al. (2015), Drupp et al. (2023b) compute the difference in growth rates of ecosystem services and human-made goods (proxied for by the growth rate of GDP per capita) over 1993–2016.

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[143] The authors conducted a meta-analysis of contingent valuation-based WTP studies using a large-scale keyword-based search strategy. The initial search resulted in 2,174 articles to which a range of exclusion criteria were applied to ensure the studies were consistent and comparable (for details see Drupp et al. 2023b). From the final set of 1,165 candidate WTP studies a random sample of 1,000 studies was analyzed in depth to ensure studies were comparable. This resulted in a final sample of 351 studies, which yielded 749 distinct WTP-income pairs.

[144] This builds on previous work by Jacobsen and Hanley (2009), Richardson and Loomis (2009), Barrio and Loureiro (2010), Subroy et al. (2019), and Heckenhahn and Drupp (2022).

TABLE 4.1

The elasticity of substitution (σ_2), by ecosystem service types

	MEAN	2.5 PERCENTILE	97.5 PERCENTILE	N
Climate regulation	1.4	0.8	4.0	183
Air quality regulation	1.3	0.9	2.0	257
Water regulation	1.2	0.9	1.7	285
Erosion regulation	1.2	0.9	1.7	195
Regulating services	**1.3**	**1.0**	**2.0**	**535**
Spiritual and religious values	1.2	0.9	1.7	121
Aesthetic values	1.5	1.1	2.3	416
Recreation and ecotourism	1.7	1.0	4.8	353
Biodiversity preservation	1.3	1.0	1.8	384
Cultural services	**1.5**	**1.1**	**2.1**	**515**
Forest ecosystem services	1.2	0.9	1.8	244
Non-forest ecosystem services	1.3	1.0	2.0	607
Aggregate	**1.3**	**1.0**	**1.8**	**851**

Source: Drupp et al. 2023b.

Their estimates suggest a sizable shift in the relative scarcity of ecosystem services relative to human-made goods. On aggregate, when taking the arithmetic mean of growth rates, which implies Cobb-Douglas substitutability among ecosystem services, ecosystem services have become relatively scarcer by nearly 1 percent per year, while GDP per capita has increased annually by almost 2 percent over the same period.

Once these estimates are combined, it comes as no surprise that the relative price adjustment, and its implications for the value of renewable natural capital, are substantial. The authors find that the value of aggregate ecosystem services is increasing by around 2.2 percent per year relative to human-made goods. Similarly, there is a substantial uplift of the present value of non-wood ecosystem services by 52 percent over a 100-year period.[145] Figure 4.5 illustrates this further for the mean and 95 percent confidence interval, where the uplift increases as the degree of substitutability declines—or the complementarity between inputs increases. For aggregate ecosystem services, the uplift in the present value would be around 90 percent. These results clearly highlight the importance of accounting for limited substitutability in wealth accounting and echo similar results for climate policy appraisal (Bastien-Olvera and Moore 2021; Drupp and Hänsel 2021; Sterner and Persson 2008).[146]

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[145] This relative price adjustment of 1.6 percent is equivalent to an ecological discount rate of 2.4 percent.

[146] This emerging literature has studied how optimal climate policy is affected by increasing scarcity and limited substitutability of non-market ecosystem services relative to manufactured goods, using good-specific discount rates and relative price changes.

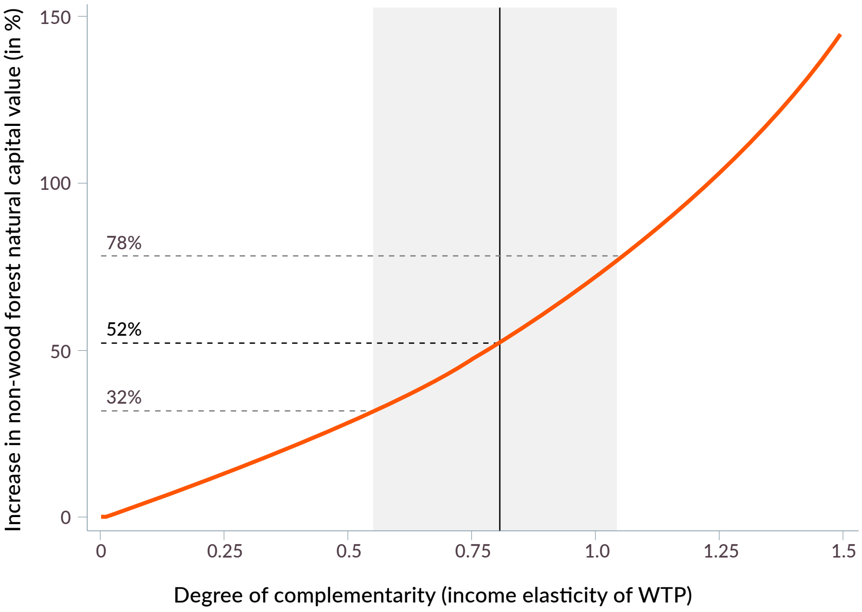
BOX 4.1
FORESTS AS COMPLEMENTS TO HUMAN HEALTH

Forest loss is often a consequence of economic activities that bring market and other benefits. However, at the same time, it can adversely affect the provision of forest ecosystem services and the associated socioeconomic and environmental benefits that rural communities enjoy. Which effect dominates is an empirical question. Damania et al. (2023) focus on the possible complementarity between human and natural capital, particularly the health benefits of clean water provided by an intact forest ecosystem. By linking high resolution deforestation data with health outcomes for 0.7 million children across 46 countries, they analyze how deforestation upstream impacts waterborne disease outcomes for rural households downstream.

The results indicate increases in diarrheal disease incidence among children under 5 years old. They also offer new evidence of early-life exposure to deforestation on childhood stunting, which is a well-known indicator of later-life productivity. A series of robustness checks confirms that the transmission mechanism is the water channel, where deforestation upstream impacts water quality and thus health outcomes downstream. Therefore, maintaining natural capital, in this case an intact forest ecosystem, has the potential to generate meaningful improvements to long-run human capital.

FIGURE 4.5

The value of non-wood forest ecosystem services, by the degree of substitutability



Source: Drupp et al. 2023b.
Note: The degree of complementarity corresponds to the income elasticity of the willingness to pay (WTP) and is the inverse of the degree of substitutability. The red line in this figure shows the estimated increase in CWON's non-timber forest natural capital value (in percent) relative to the current CWON's estimate, as a function of the degree of complementarity between forest ecosystem services and human-made goods, measured by the income elasticity of the WTP for forest ecosystem services. The vertical black line indicates the central estimate, while the gray-shaded area indicates its 95 percent confidence interval. Horizontal dashed helplines indicate the corresponding increase in the public natural capital value (in percent).

CONCLUSIONS AND WAY FORWARD

The emerging research has clearly shown that limited substitutability is of critical importance from an economic development point of view, as it has significant implications for the long-run growth potential of an economy as well as for its resilience and fragility to natural shocks. Failing to account for limited substitutability in wealth accounting also provides the wrong signal to policy makers on the importance of renewable natural capital as part of their broader wealth portfolio. By focusing on assets that are critical to sustainability and whose depletion brings high economic costs, natural capital accounting has an opportunity to highlight the economic significance of the complementary role played by natural assets in sustaining economic growth.

In sum, where substitutability between assets is limited, the effective shadow price needs to be adjusted to account for the losses that could ensue from depleting natural capital stocks. Theoretically, there are two equivalent ways of achieving this adjustment—through differentiated discount rates or by relative price adjustments. However, the ease of implementation varies greatly across the two options and experience in using either is limited (Groom et al. 2022). Implementing differentiated discount rates is straightforward, but more research is needed to determine which set of discount rates CWON should use. Relative price adjustments are a more targeted way to adjust shadow prices; however, estimating such relative prices for all assets is a complex task. More research and data are needed to implement such adjustments in the medium term.

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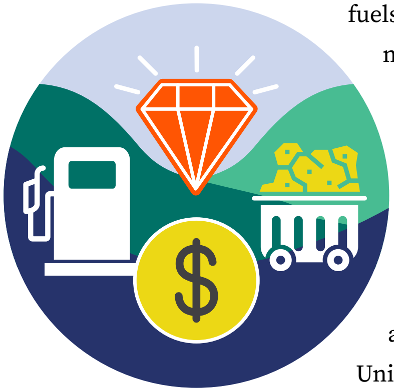
II. Measuring Components of Comprehensive Wealth

5 The Nonrenewable Wealth of Nations

MAIN MESSAGES

- Nonrenewable natural capital wealth per capita decreased by 1 percent globally between 1995 and 2020. The trend was volatile, with periods of fast growth in the underlying asset base caused by discoveries and technological innovations followed by sudden declines in wealth driven by increased extraction.
- Most nonrenewable natural capital assets declined in per capita terms between 1995 and 2020, with the exception of oil, which flatlined. In total terms, oil, natural gas, and minerals increased, with oil increasing the most, and minerals the least, while coal declined 7 percent.
- Nonrenewable natural capital remains highly concentrated across countries, particularly in petrostates. Despite the share of nonrenewable wealth in global total wealth being only 2 percent in 2020, 10 countries have more than 20 percent of their total wealth in nonrenewable assets and another 11 countries have more than 10 percent.
- Metals and minerals are becoming an increasingly valuable asset, increasing as a share of nonrenewable wealth across all regions over the last quarter century. In 2020, global metals and mineral wealth was worth as much as global oil wealth. New critical minerals added to the balance sheet (cobalt, lithium, and molybdenum), increased in per capita terms by 31 percent.



INTRODUCTION

Nonrenewable natural capital encompasses subsoil geological assets, including oil, gas, coal, metals, and minerals. Unlike renewable biological resources, these assets do not grow or regenerate over a meaningful economic time frame.[147] However, each has distinct characteristics that makes them valuable commodities and important inputs into the production and consumption activities of modern economies. Fossil fuels are primarily used for energy, and metals and minerals have a plethora of uses, including the production of steel, electronics, chemical production, fertilizers, jewelry, and batteries. A country's nonrenewable asset endowment is mostly a factor of geology, and discovered through exploration. Prominent recent examples include the exploitation of oil and natural gas in shale formations in the United States and the filtration of lithium from underground brine in the deserts of Latin America. Changing preferences, demand, and environmental policy may affect the economic viability of extraction.

Alongside the beneficial uses of nonrenewable natural capital, the mining, combustion, and transformation of these resources leads to costly pollution and effluents, which must be absorbed by the environment and ecosystems. This pollution has contributed to the earth transgressing several planetary boundaries (Richardson et al. 2023) and is the leading cause of climate change (IPCC 2023). To address these challenges there are now well-developed international agreements in place, with countries committing to reduce their production of fossil fuels in the coming decades (Paris Agreement 2015) and reverse the loss of biodiversity (Kunming-Montreal Agreement 2022). The decarbonization of the global economy means that society is likely to shift from using fossil fuels to renewable energy and new technologies, and at a scale that requires a high volume of primary metals and previously less-exploited critical minerals.

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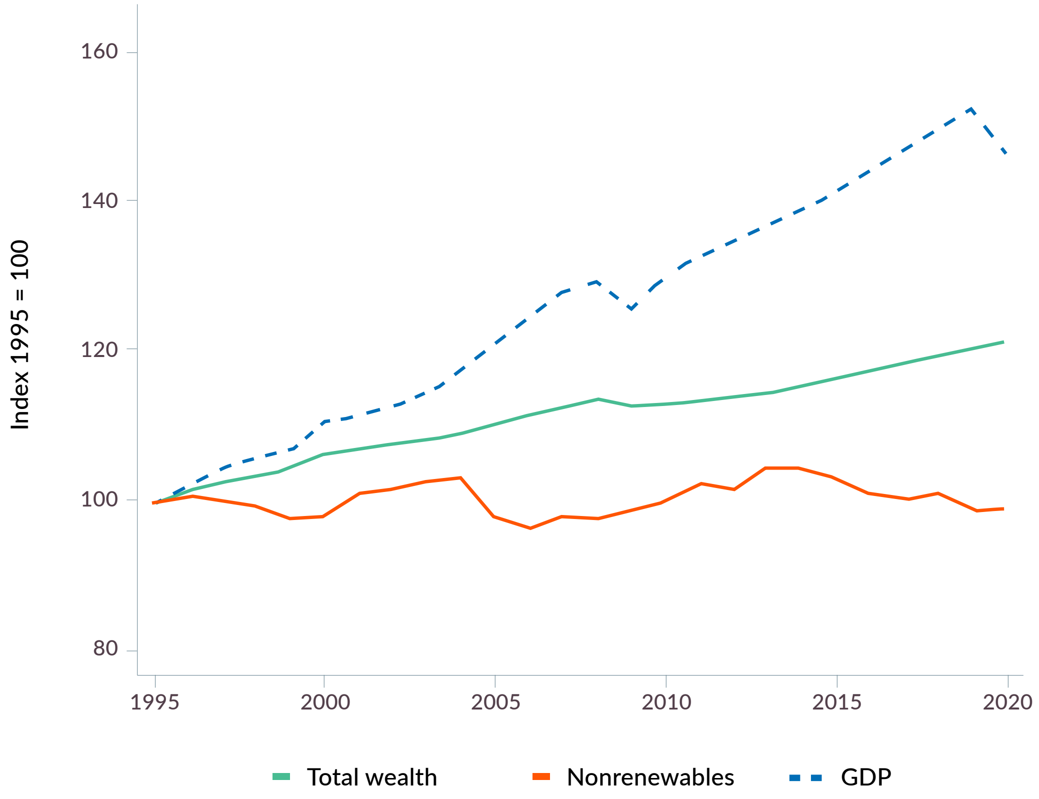
[147] Conrad (2010) defines a relevant economic time scale as one over which planning, and management decision are meaningful. Subsoil assets like oil and gas are formed over millions of years.

This presents both risks and opportunities. Nations rich in nonrenewable resources have historically had mixed success turning these endowments into economic prosperity (Van Der Ploeg 2011; Frankel 2012; Ross 2015). Sustainable development requires that resource rents from nonrenewable assets be reinvested into other assets (Hamilton and Hartwick 2014; Hartwick 1977, 1990). But, although the taxation of these resources contributes to the economy, many resource-rich countries have failed to develop a resource tax base due to under-exploration or an inability to raise proportionate tax revenues from exploited subsoil assets (Readhead et al. 2023). As the world seeks to decarbonize, relying on the continued rents from fossil fuels is unlikely to be a sustainable development pathway. The possibility that assets in the fossil fuel industry will become stranded[148] (Van der Ploeg and Rezai 2020) suggests that countries should diversify their asset portfolios with greater urgency (Peszko et al. 2020).

Therefore, whether a policy maker wants to assess the fiscal sustainability of a fossil-fuel-rich state or is deliberating the viability of extracting untapped oil reserves, each of these contexts necessitates an analysis and interest in the changing level and composition of nonrenewable wealth.

FIGURE 5.1
Global comprehensive wealth, nonrenewable natural capital, and GDP in per capita terms, 1995–2020



Source: World Bank staff estimates.
Note: Wealth is measured in chained 2019 US dollars.

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[148] Assets that end up as a liability before the end of their anticipated economic lifetime. https://www.lse.ac.uk/granthaminstitute/explainers/what-are-stranded-assets.

Unfortunately, the most prominent metric used to analyze economic progress, GDP, does not account for the economic damages from exploiting nonrenewable resources or the sustainable reinvestment of economic rents (Hoekstra 2019). Comprehensive wealth, and the nonrenewable natural capital component, go some way to addressing these measurement shortcomings (see chapter 1). This is clearly illustrated in Figure 5.1, which shows that global GDP per capita increased by over 40 percent in the last quarter century, yet nonrenewable natural capital has barely changed, and the overall comprehensive wealth per capita has increased by less than half of global GDP per capita. While the size of the global economy has increased, the stock of nonrenewable natural capital has slightly decreased. Growth in income, therefore, has been in part accompanied by a reduction in nonrenewable natural capital wealth, even if the estimates of nonrenewable natural capital presented here are conservative upper bounds (Atkinson and Venmans 2024; McGlade and Ekins 2015). A scenario-based analysis of nonrenewable natural capital wealth exploring how likely price, extraction, and use changes affect wealth due to decarbonization and net-zero commitments would be a worthwhile exercise, but is beyond the scope of this report.

The rest of this chapter first briefly recaps how nonrenewable natural capital wealth is measured in CWON. It explains the intuition of the volume-based index for nonrenewable resources and outlines the data sources at a high level. Next, the chapter presents the global trends for fossil fuels, metal, and mineral wealth. It looks at how the value of each nonrenewable resource is changing over time, and at distributions by region and income groups. As nonrenewable natural capital wealth is highly concentrated, the analysis then focuses on the 10 countries that hold more than half of the world's share in nonrenewables. A further section explores metals and minerals, including the wealth in new critical minerals added to the data in this report. The final section concludes by discussing the next frontier for global nonrenewable wealth accounts.

MEASURING NONRENEWABLE NATURAL CAPITAL

The nonrenewable natural capital estimates produced for this edition of CWON build on a nearly 20-year effort by the World Bank to develop globally consistent wealth accounts for nonrenewable natural resources (World Bank 2005, 2011, 2021; Lange et al. 2018). The first estimates of subsoil assets were produced in the World Bank's Where Is the Wealth of Nations publication, which used an NPV approach to capitalize an assumed flow of future resource rents for nonrenewable resources. Each report since has introduced incremental improvements to the accuracy of wealth estimates by gathering better-quality and more extensive data on resource production and reserves, and improving the valuation approach.[149] All previous reports have attempted to align with the latest globally agreed statistical standards provided by the United Nations SEEA-CF, which outlines how to appropriately measure resource depletion and asset values.

In the previous edition of CWON, Managing Assets for the Future, measures of nonrenewable wealth were decomposed to analyze the underlying changes in wealth (World Bank 2021). The report and a technical background paper found that changes in prices (applying GDP deflators) and production in the current period were the main drivers of changes in nonrenewable natural capital wealth (Hoekstra 2021). Volatile commodity prices can provide counterintuitive signals for long-term sustainability—where prices increase despite a resource being overexploited, causing an increase in capital gains in the sustainability metric. Following a methodological review, this edition of CWON makes several significant methodological improvements:

- Changes in nonrenewable wealth are estimated using a **volume-based index**, where changes in the physical quantities or "volumes" of each asset are weighted according to its economic value (as measured by their share in nominal wealth). Changes in nonrenewable natural capital wealth over time are now primarily

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[149] An example of this was the improvement introduced in Lange et al. (2018), which moved from assuming a fixed lifetime of nonrenewable resources of, say, 25 years, to the direct estimation of the remaining lifetime of resources based on proven reserves and resource extraction levels.

driven by physical changes in proven reserves of each asset (for example, economically recoverable barrels of oil, kilojoules of naturas gas, tons of coal, and so on). The economic value and market price of the resource still affects nonrenewable natural capital wealth in so far as it affects the relative price of assets, and the weighting placed on each asset in the wealth series. This advancement removes potentially misleading signals from volatile prices. Removing what are likely to be short-term capital gains aligns the methodology more closely with the economics of sustainability (Atkinson and Venmans 2024).

- **The resource rent estimates** were improved by (i) directly measuring the "user costs of capital" in the extraction of nonrenewable assets (that is, costs from the use of machinery and physical premises); (ii) using country-level rents rather than regional average rents for all assets where data are available; and (iii) more precisely estimating operating costs in the mining sector.
- Three new critical metals have been added to the nonrenewable natural capital account: **cobalt, lithium, and molybdenum**. These metals have a range of increasingly important uses, from lithium-ion batteries used in electric vehicles and mobile phones,[150] to cobalt used in rechargeable battery electrodes,[151] to molybdenum used as an important additive in steel manufacturing.[152]

These methodological changes lead to marked differences with past results. However, the new estimates should provide more intuitive and interpretable results, while continuing to align with the SEEA standards and economic theory and making the nonrenewable asset account coverage more complete.

CALCULATING THE NONRENEWABLE WEALTH OF NATIONS

Estimating the nonrenewable wealth of nations is a challenging task. Unlike financial assets, such as stocks or bonds, where an asset class may be homogenous and feasibly sold in its entirety on a specific auction date, nonrenewable resources are heterogenous[153] and extracted and sold gradually over time. As described in chapter 2, there are two important aspects to estimating the real nonrenewable natural capital: the physical volume and the economic value of the asset. With data on volumes and value, a volume-based index can be estimated, which changes over time according to the change in the physical volume of each nonrenewable asset and is weighted according to each asset's economic value.

For nonrenewable assets, the volumes of each asset are the proven reserves in units of barrels for oil, kilojoules for natural gas, and tons for coal and metals and minerals. To grasp the intuition of the index, suppose only changes in the physical volumes of assets are considered without any economic weighting. This may be an interesting exercise for a geological agency interested in the pure scarcity of a given nonrenewable resource, but it is not of much use for a sustainability assessment if the asset has no economic value. Therefore, each asset in the volume index is weighted by its economic value. It is possible that once a nonrenewable geological resource is mined, it may be stored as an economic or financial asset in another form. Gold, for example, is often held in reserve by governments and investors, or in the form of jewelry, which may hold its value. To some extent, extracted geological and mineral assets, depending on their uses, will be part of the produced capital account, such as minerals like copper (electric wiring), iron (steel structures), and lithium (computer batteries).

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[150] See the British Geological Survey (2016) profile on lithium.

[151] See the cobalt factsheet from the Cobalt Institute (2023).

[152] See the Molybdenum Commodity Summary 2023 from the United States Geological Survey (2023).

[153] For example, coal can be broadly classified into four different types or ranks anthracite, bituminous, subbituminous, and lignite. In this report, the first three types are classified into a hard coal category, and lignite into a brown coal category.

BOX 5.1

ESTIMATING THE USER COSTS OF CAPITAL FOR NONRENEWABLE NATURAL CAPITAL

Resource rents (or royalty rents) are a commonly used concept in resource economics. Economic theory on the optimal extraction of nonrenewable natural resources standardly expresses rents as the price of a resource less the marginal cost of extraction. In CWON, and economic-environmental accounting, rents are used to estimate the value of the stock of the resource in situ using an NPV calculation. As explained in chapter 2, the resource rent is calculated as the difference between revenues from extraction, the cost of extraction from intermediate inputs, labor, and the user cost of produced capital used in the extraction process. The user cost is the sum of both the “normal” returns to fixed assets (for example, the economic returns to machinery used in the extraction process) and depreciation. The opportunity cost of foregone rental returns from using the machinery and the depreciation of this machinery should be deducted from the economic rent (or profits) of extracting the resource.

The estimation of user costs for a global database, however, is not an easy task. In the absence of estimates of capital stocks for the fossil fuel and mineral industries in a country, capital stocks need to be estimated from capital expenditure. Then a reasonable estimate for the return on capital and depreciation is needed to estimate the user costs from these estimates of capital stock. For oil and gas, country-level capital expenditure data are available from the Rystad database. For coal and metals and minerals, capital expenditure data are available at the mine level from Wood Mackenzie and S&P, respectively. Following the *OECD’s Measuring Capital—OECD Manual (2009)*, the capital expenditure series was converted into capital stock estimates for the longest historical series available in the data. This was done using estimates for an industry-specific rate of return for capital and depreciation to estimate an initial capital stock for time 0, and then adding capital expenditure year-on-year to complete the series. These completed estimates of capital stocks for each asset can then be multiplied by rates of return plus depreciation rates to get the user costs.

The estimation of user costs affects CWON’s results by changing the economic value of nonrenewable assets and thus the weights placed on the volume changes in the wealth series. Including user costs in the rent calculation would increase rents when the user costs are lower than capital expenditure but would decrease the rents when user costs are greater than capital expenditure. Globally, the inclusion of user costs increased rents for oil, gas, and metals and minerals, but reduced rents for coal. This effect, however, varies across regions and may reflect differing levels of capital expenditure and industrial investment. As this is a relatively new addition to CWON, further analysis and data collection are needed to fully assess and improve the estimation of user costs.

However, there are likely to be some gaps. Where extracted minerals are used as pure stores of value, they could be thought of in the same way as domestically held financial assets, which CWON does not account for, on the basis that these are pure stores of value to be transferred into other assets in the comprehensive wealth index.

Following the valuation approach recommended by the SEEA and used in previous editions of CWON (World Bank 2011, 2018, and 2021), nonrenewable natural capital assets are valued using the NPV of the future returns of the resource in situ, where future returns are a stream of discounted rents for the lifetime of the resource, defined as proven reserves divided by current-year extraction. Within this calculation, rents from the current year are estimated and held constant for all future years within the NPV formula. Rents are calculated as revenues less operating costs and the user costs of produced assets used in extraction.

Revenues are calculated as market prices multiplied by the quantity of production of a resource. For each asset, estimates of rents are averages for that resource across all the extraction or mining projects in a country. Oil and natural gas use data from Rystad Energy's UCube database, which takes the nearest geographical price benchmarks, such as Brent or West Texas Intermediate, and a combination of cost data from company statements, interviews, and modelling. For coal, Wood Mackenzie's Global Economic Model (GEM) data are used. This is a bottom-up, mine-level database of prices and costs, with recent data covering 15 countries and up to 269 mines.[154] For metals and minerals, price data come from the World Bank's Global Economic Monitor Commodities database and S&P's Global Market Intelligence database, which has data on realized prices at the mine level. All cost data from minerals come from the S&P database across 13 metals and minerals.[155]

GLOBAL TRENDS IN NONRENEWABLE WEALTH

Globally, nonrenewable natural capital per capita declined by 1 percent between 1995 and 2020, coinciding with a global commodity price boom between 2000 and 2014. Nonrenewable natural capital wealth was volatile over the reporting period, and partly reflects the depletion of specific assets, but also global population growth, which increased by 36 percent over the reporting period (Figure 5.2). While oil wealth per capita flatlined, gas, coal, and minerals all declined in per capita terms. In absolute terms, natural capital increased by 35 percent between 1995 and 2020, driven mainly by increases in oil (37 percent), gas (34 percent), and metals and minerals (23 percent). Not all nonrenewable assets increased in absolute terms. Coal wealth has declined by 8 percent globally, a trend that can be observed across all regions and income groups.

Nonrenewable wealth can be volatile, as shown in Figure 5.2, likely reflecting years of significant discoveries or exploration of economically recoverable resource reserves. Of the resources, global trends in coal are the smoothest, reflecting a stagnant trend in global proven coal reserves, reductions in exploration, and methodological limitations in the data collection process for coal reserves.[156]

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[154] This is a small improvement in coverage compared to World Bank (2021). However, as country coverage for coal costs and thus rental rates is limited, the coal accounts rely on a large share of regionally averaging. Future updates to the report may seek to widen the data coverage specifically for coal rents and cost shares.

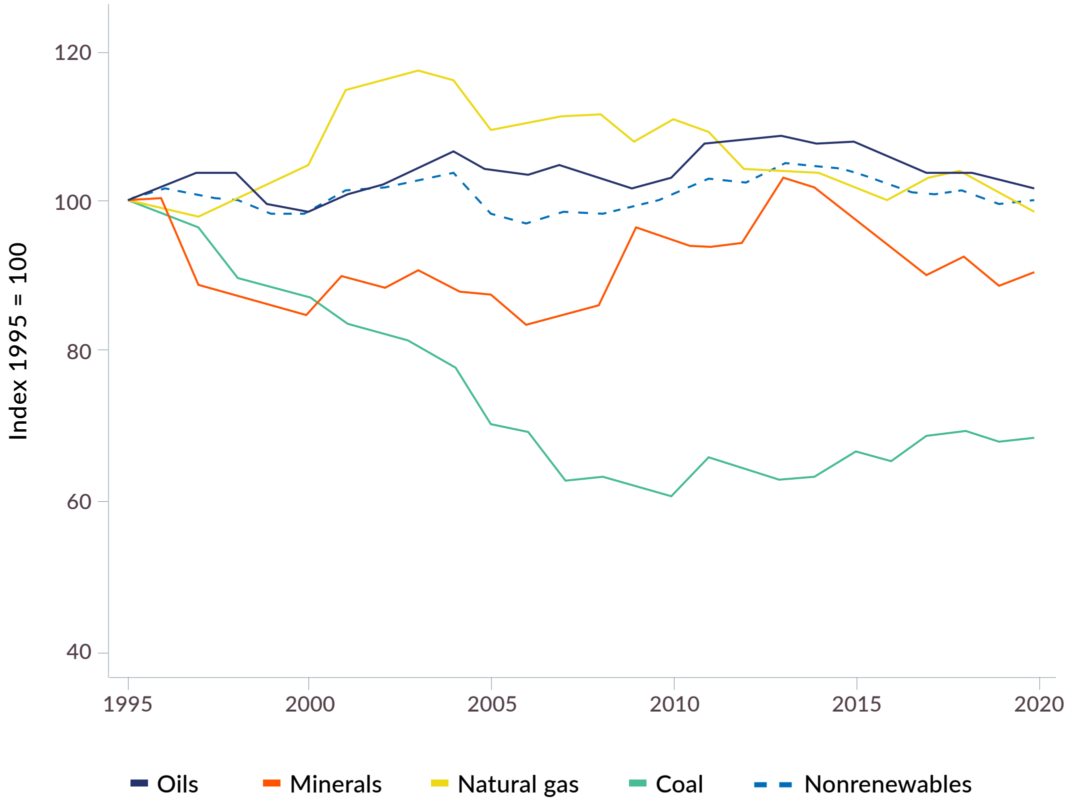
[155] For assets and data sources without complete global coverage such as coal (Wood Mackenzie) and minerals (S&P), a range of gap-filling approaches are used to complete series. If coal cost data are missing for a country, a regional or global average is used. The cost data for three minerals (bauxite, phosphate, and tin) are estimated using an index of costs from seven other minerals as cost data for those minerals were not found in S&P.

[156] Obtaining data on global coal reserves is challenging and the main source used in this report, the US Energy Information Administration (EIA), only reports data on coal reserves back to 2005, so the remainder of the series is from alternative sources and gap-filling approaches. Trends in coal reserves assessed from other sources, such as the BP Statistical Review of World Energy, show relatively flat lines for global coal reserves, so the smooth decline observed in the above data may reflect the interacting effects of population growth and stagnant coal reserves. The team is seeking out an improved method to estimate coal reserves.

Changes in the proven reserves of a given resource will be reflected in the overall nonrenewable wealth series, to the extent that the resource is of significant economic value. As shown in Figure 5.3, oil and gas account for a high of 87 percent of nonrenewable wealth in 2000 and a low of 53 percent in 2020. Therefore, nonrenewable natural capital trends track the trends in oil and gas most closely. In contrast, while coal has been declining both in absolute and per capita terms, the resource has an average share of 10 percent—though this fluctuates from a high of 20 percent in 2010 to a low of 5 percent in 2000—so declines in coal wealth had a smaller effect on the overall trend in global nonrenewable wealth.

FIGURE 5.2

Change in global nonrenewable natural capital per capita, by asset, 1995–2020

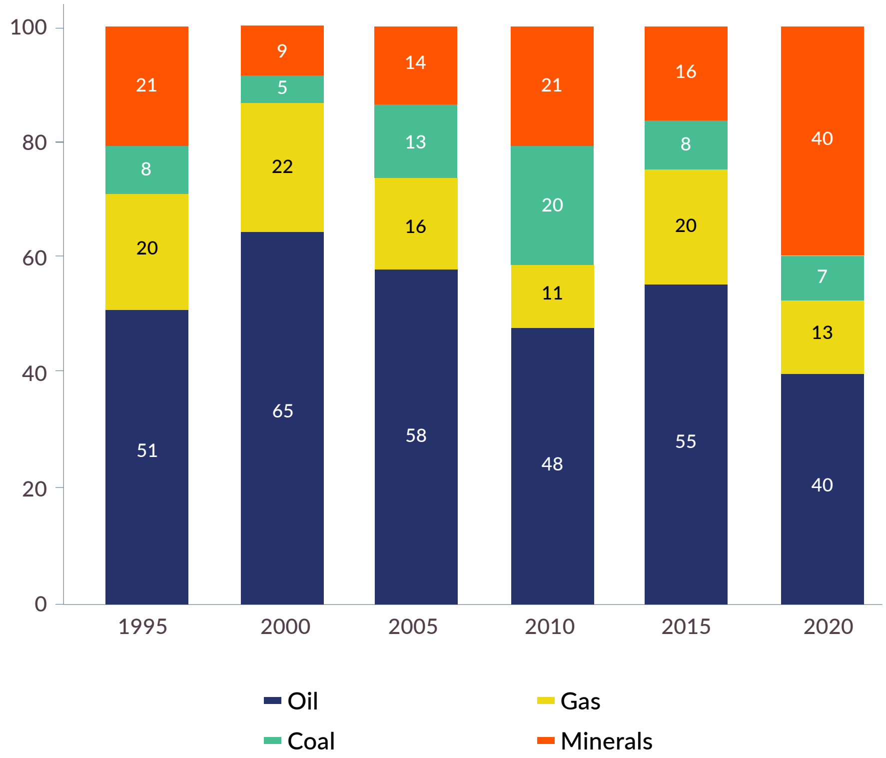


Source: World Bank staff estimates.

Note: Wealth per capita is measured in chained 2019 US dollars. There are large data gaps for coal reserves at the country level and stagnant trends globally, which are causing a smooth decline in coal reserves per capita.

FIGURE 5.3

Shares of nonrenewable wealth, global, 1995–2020



Source: World Bank staff estimates.

Note: Shares of assets are calculated as shares of nominal wealth rather than the volume-based estimates. Shares represent the weights each asset is given in the volume index.

Table 5.1 shows the breakdown of changes in nonrenewable wealth per capita by region and income group. Over half of the regions in the world had a decline in nonrenewable wealth per capita between 1995 and 2020. The largest growth was in East Asia and the Pacific (59 percent), particularly due to increases in mineral wealth (89 percent). This growth is largely driven by China, where mineral wealth increased from $78 per capita to $238 per capita, with discoveries of particularly large reserves of copper, molybdenum, and zinc. The other region with large gains was North America, which had significant increases in oil and gas wealth per capita. Although the Middle East and North Africa had very high growth in absolute terms, nonrenewable wealth declined in per capita terms by 12 percent over the reporting period. At the same time, several regions struggled to maintain their nonrenewable natural capital wealth. Sub-Saharan Africa, for example, had declines across every nonrenewable asset category (see Figure 5.4), with the exception of Botswana and Mozambique, which discovered large deposits of natural gas in recent years.

TABLE 5.1

Percent change in nonrenewable natural capital per capita, by asset, region, and income group, 1995–2020

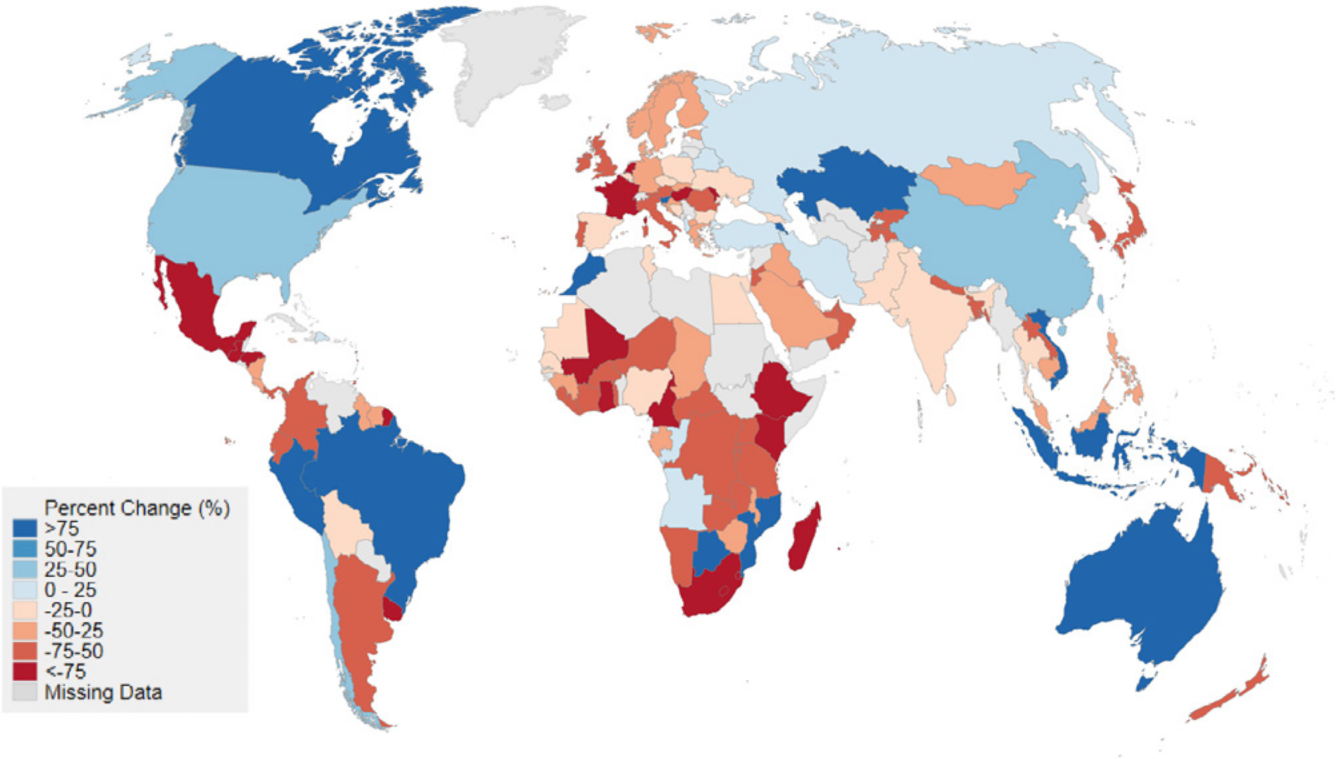
	NONRENEWABLES	OIL	GAS	COAL	MINERALS	POPULATION
Region						
East Asia and the Pacific	59	11	37	10	89	22
Europe and Central Asia	4	8	-13	-18	-32	6
Latin America and the Caribbean	-21	-63	-54	-28	38	36
Middle East and North Africa	-12	-16	13	274	-30	67
North America	38	108	127	-19	-58	25
South Asia	-17	-44	-29	9	-33	47
Sub-Saharan Africa	-61	-6	-17	-90	-77	95
Income group						
High income	30	21	20	-3	34	16
Upper middle income	3.4	7.4	0.5	-51	4	24
Lower middle income	-17	0.8	8	-4	-56	52
Low income	-56	-43	1,093	166	-63	104
World	**-0.7**	**1.1**	**-1.7**	**-32**	**-9.9**	**36**

Source: World Bank staff estimates.
Note: All figures are the percent change to the nearest whole percentage point calculated from changes in real asset values per capita.

Across income groups, there has been a notable global divergence between 1995 and 2020 in nonrenewable natural capital per capita between high-income and low-income countries. While nonrenewable wealth per capita rose by 30 percent in high-income countries, it fell by 56 percent in low-income countries, which represents a widening of international inequities in global nonrenewable natural capital wealth. This is an unfortunate story, particularly from the perspective of improving living standards in low-income countries and reducing levels of global poverty. Moreover, this aligns with recent evidence showing a global divergence in income levels across rich and poor countries since 2015, following a "golden decade" of convergence between 2004 and 2014 (Cust et al. 2024).

FIGURE 5.4

Change in nonrenewable natural capital wealth per capita, 1995–2020



Source: World Bank staff estimates.
Note: Wealth per capita in chained 2019 US dollars. Blue represents increasing wealth per capita, red decreasing.

COUNTRIES WITH HIGH NONRENEWABLE NATURAL CAPITAL WEALTH

At a country level, it is common to analyze the extent to which countries are rich in resources, which implies their economic prospects are likely to be dictated by how well they manage natural resource endowments. Resource-rich economies are most often defined as countries with a high share of nonrenewable resource exports as a share of total export receipts or as a share of total tax revenues (IMF 2012). Recent analysis has found that the number of resource-rich countries is growing in certain regions in the world. For example, Cust and Zeufack (2023) found that the number of resource-rich countries in Sub-Saharan Africa rose from 18 to 26 between 2004 and 2014.

The world's nonrenewable natural capital is concentrated in specific countries, some of which are resource rich and others which are not. In 2020, more than half of the world's nonrenewable natural capital wealth was concentrated in 10 countries (Australia, Brazil, China, India, Iran, Iraq, Qatar, the Russian Federation, the United Arab Emirates, and the United States), half of which are resource rich.[157] Brazil experienced the highest nonrenewable wealth per capita growth at 98 percent, followed by Australia at 92 percent, the United States at 33 percent, and China at 32 percent.

The drivers of change varied significantly. In China, Brazil, and Australia, metals and minerals were the primary driver of increasing wealth, reflecting increases in proven reserves across a range of minerals. Fossil fuel reserve increases, on the other hand, were the main drivers of change in large petrostates such as Qatar and Iran, although in Qatar's case this did not lead to per capita increases.

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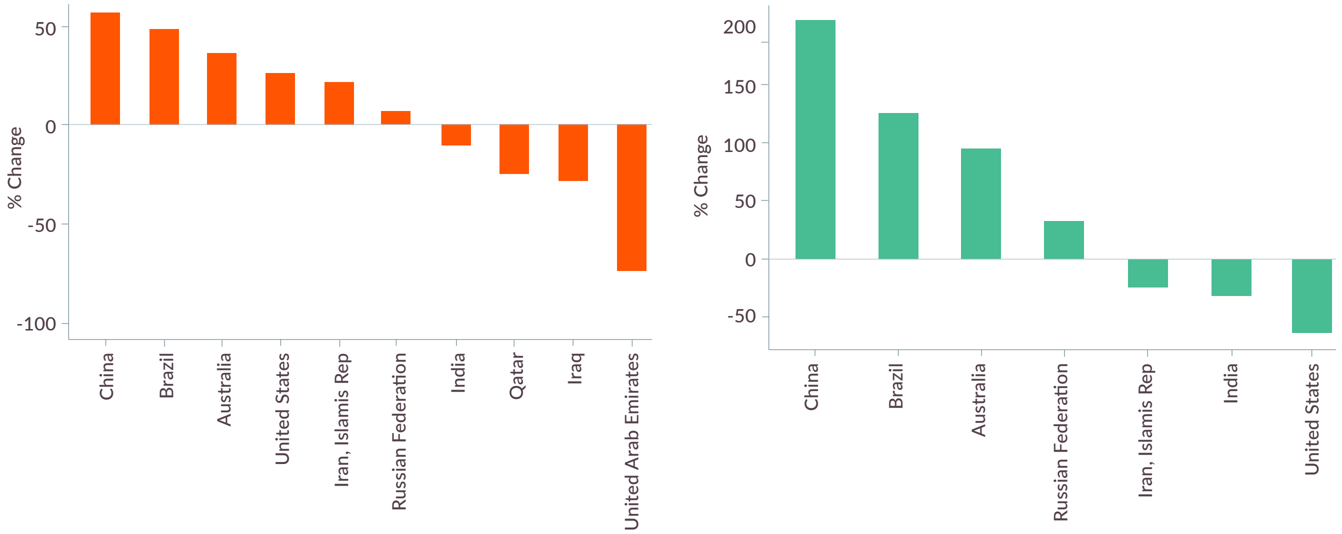
[157] Resource-rich countries within the top 10 nonrenewable natural capital list include Iran, Iraq, Qatar, Russia, and the United Arab Emirates.

FIGURE 5.5

Change in fossil fuel and mineral wealth, top 10 countries, 1995–2020

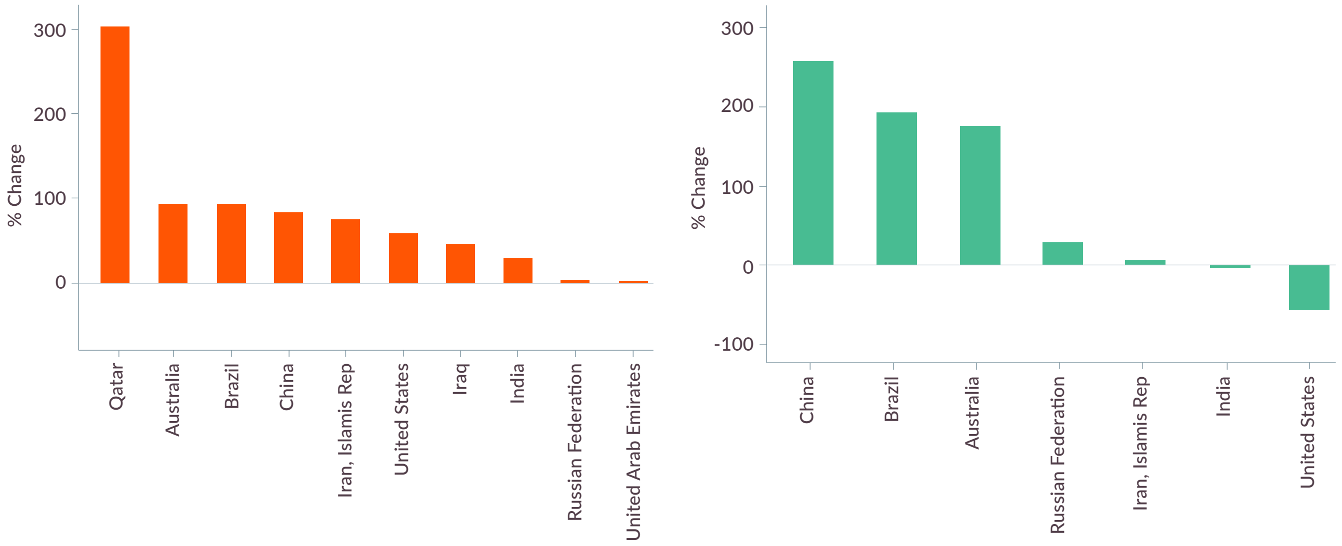
Panel a: Fossil fuels per capita

Panel b: Metals and minerals per capita



Panel c: Fossil fuels

Panel d: Metals and minerals



Source: World Bank staff estimates.

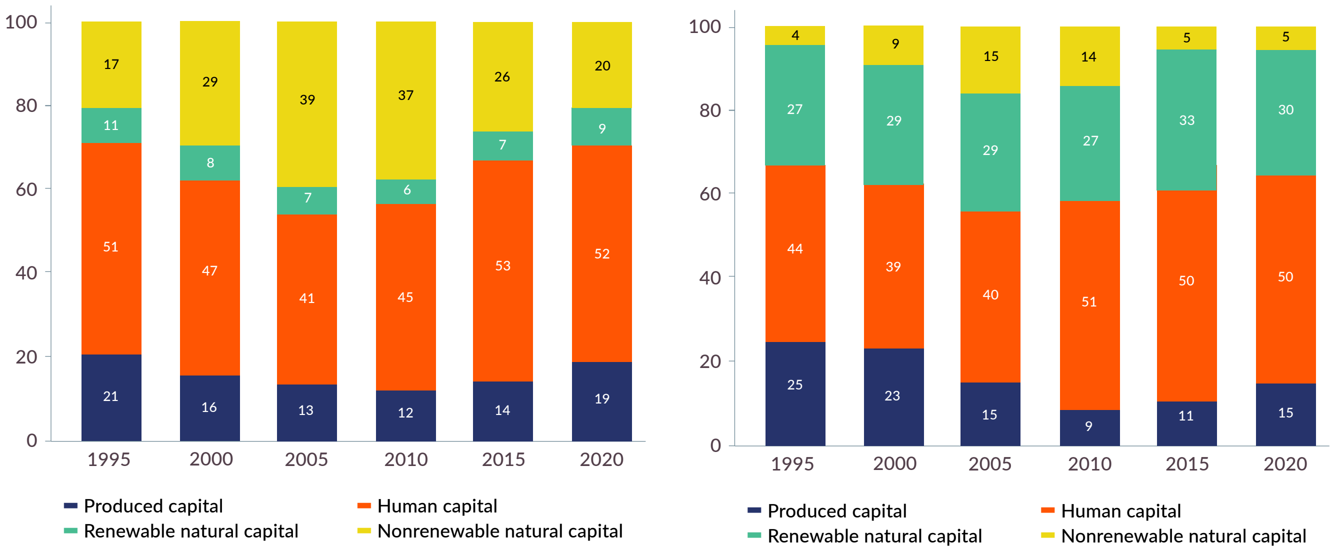
Note: Percentage changes in chained 2019 US dollars. Selected countries are the 10 countries with the highest current US dollar wealth in nonrenewables in 2020.

THE VALUE OF NONRENEWABLE NATURAL CAPITAL IN TOTAL WEALTH

The value of nonrenewables matters to the economics of sustainability for at least two reasons. First, it provides the weight, adjusted over time according to relative value, given to nonrenewables as a whole within the comprehensive wealth index. Second, it provides the weight given to each nonrenewable asset within the nonrenewable natural capital series. More broadly, Gil et al. (2014) argue that an important development strategy is to diversify a country's asset base,

FIGURE 5.6

Shares of global wealth, selected regions, 1995–2020



Panel a: Middle East and North Africa

Panel b: Sub-Saharan Africa

Source: World Bank staff estimates.
Note: Shares are calculated as a share of total wealth in current US dollars.

including by reinvesting rents from natural resources into human capital and institutions, which may suggest a declining share of nonrenewable natural capital over time, or may reflect diversifying economies and development success.

As a share of global wealth, nonrenewable natural capital is small and therefore has a small weight in the global comprehensive wealth index. Nonrenewable natural capital has increased in nominal value relative to other capital assets, and therefore the share in global wealth increased from 1 percent of global wealth in 1995 to 2 percent in 2020. The large but volatile increase in nonrenewable natural capital over this period reflects a global commodity price boom between 2004 and 2014, which increased the economic value of both fossil fuels and minerals in nominal value terms (World Bank 2021, chapter 11).[158]

Despite the small, albeit growing, economic value of nonrenewable natural capital globally, it would be a mistake to conclude nonrenewables do not matter within the comprehensive wealth index at a country level, particularly as there are large differences across regions and countries. In the Middle East and North Africa, for example, nonrenewables ranged from 17 percent to 39 percent of wealth between 1995 and 2020, and in Sub-Saharan Africa from 4 percent to 15 percent. This is shown in Figure 5.6, where the largest share for nonrenewables (assessed at five-yearly intervals) is in the period 2005 to 2010 for both regions, reflecting the commodity price boom at this time.

The economic value of each nonrenewable resource will determine the extent to which the increase or decrease

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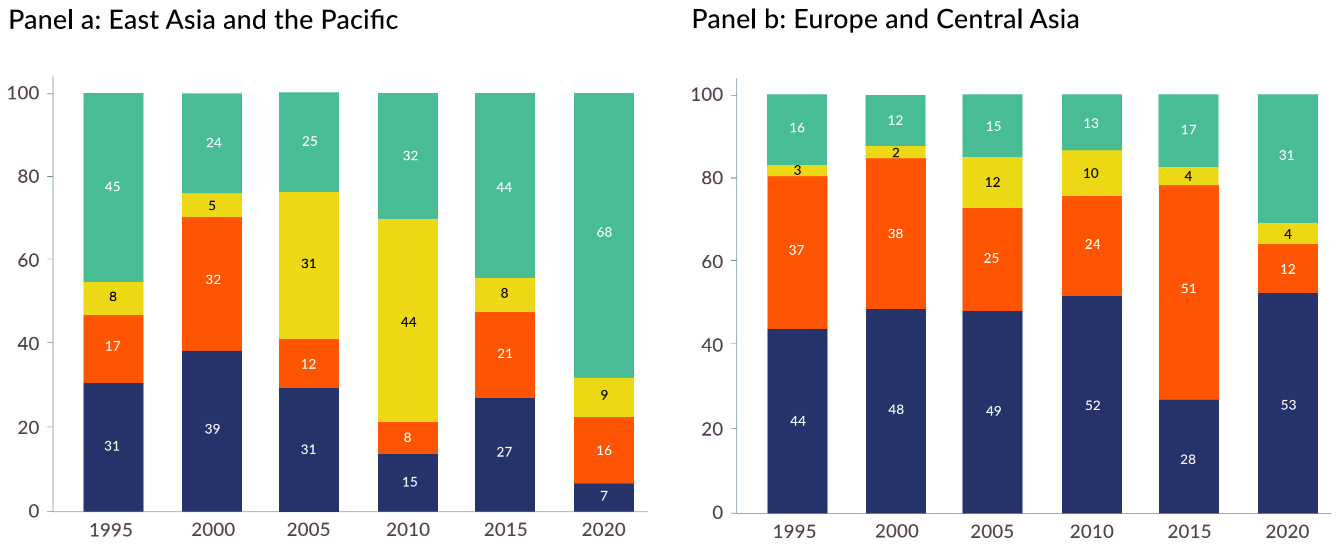
[158] Note, these increases in value are different to changes in the volume-based index of wealth. Changes in value affect the weighting given to changes in the volumes of each asset in the wealth indexes.

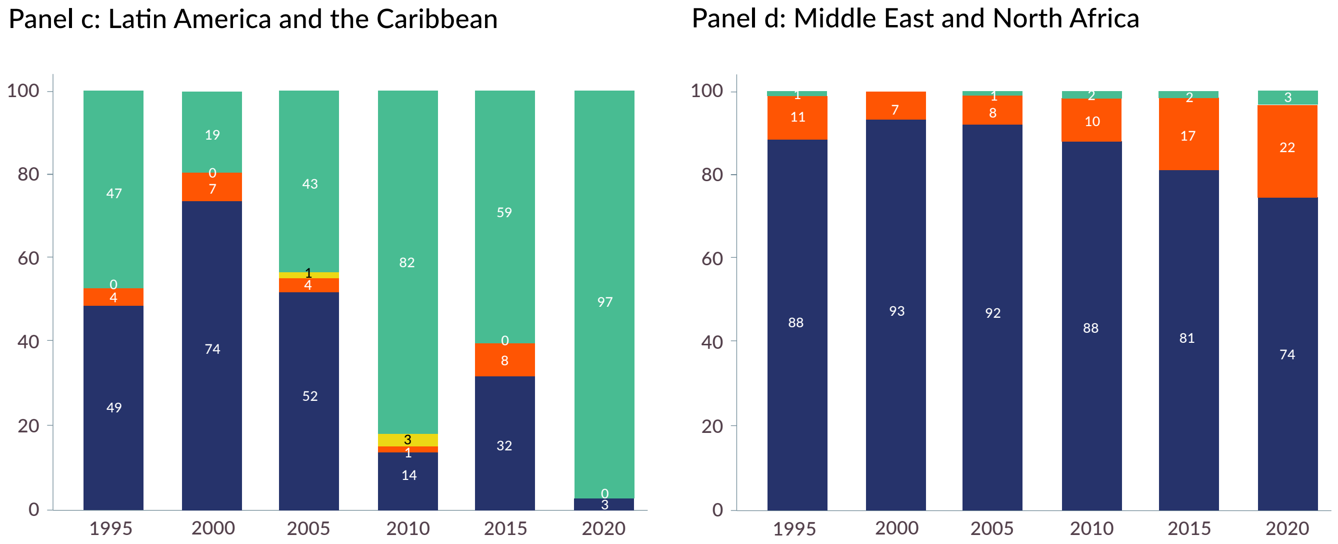
in physical reserves of, say oil, changes the aggregate nonrenewable wealth index. The shares of different nonrenewables are highly variable across space and time. Like differences in the proven reserves, this is a factor of geological diversity, preferences, demand, and environmental policy. Figure 5.7 shows, for example, that metals and minerals represent a large share of nonrenewable wealth in East Asia and the Pacific (Panel a) and Latin America and the Caribbean (Panel c). East Asia and the Pacific has some notable metal-rich nations, such as Australia and China, but also Papua New Guinea and the Philippines. Latin America and the Caribbean is mineral rich across the continent, with notable countries including Argentina, Brazil, and Chile. Across every region, the share of minerals increases over time between 1995 and 2020, which reflects the increasing economic demand for minerals.

Europe and Central Asia (Panel b), the Middle East and North Africa (Panel d), North America (Panel e), and Sub-Saharan Africa (Panel g) are relatively richer in fossil fuels.

FIGURE 5.7
Shares of nonrenewable wealth, by region, 1995–2020


Panel a: East Asia and the Pacific

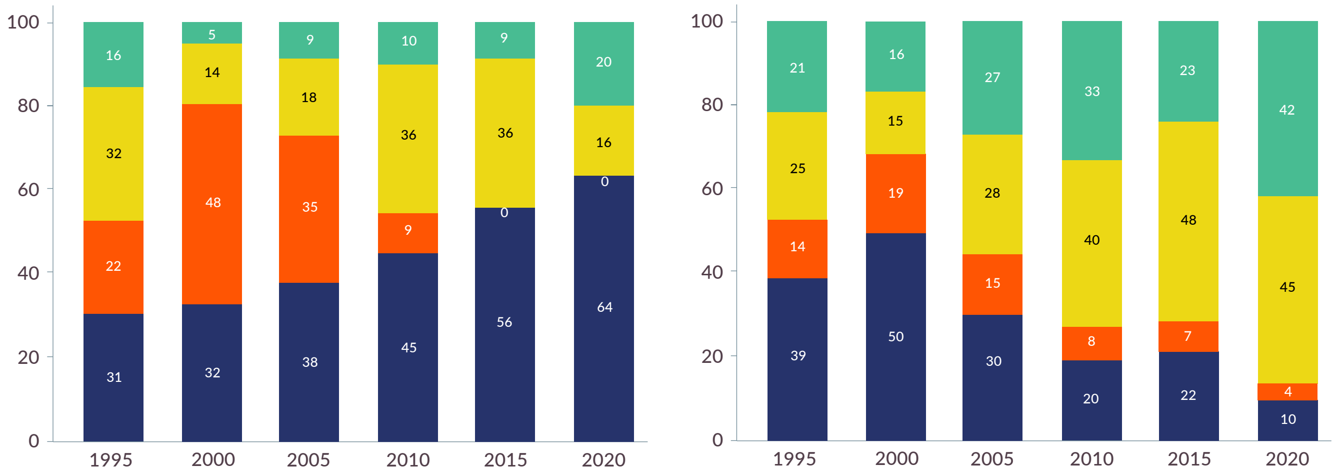
Panel b: Europe and Central Asia


Panel c: Latin America and the Caribbean

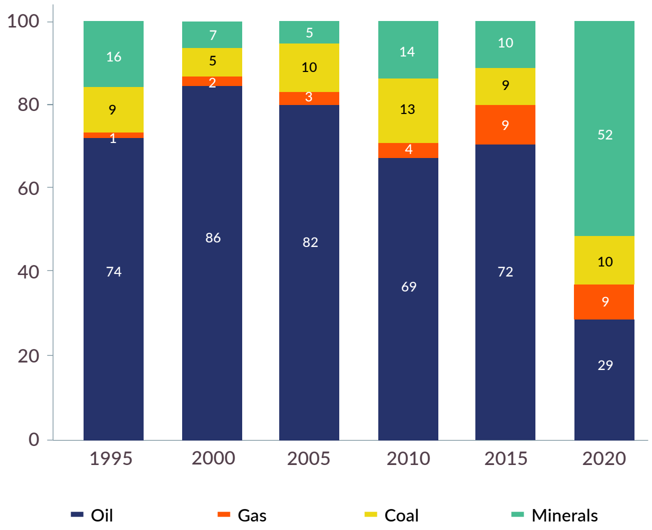
Panel d: Middle East and North Africa

Panel e: North America

Panel f: South Asia



Panel g: Sub-Saharan Africa



Source: World Bank staff estimates.

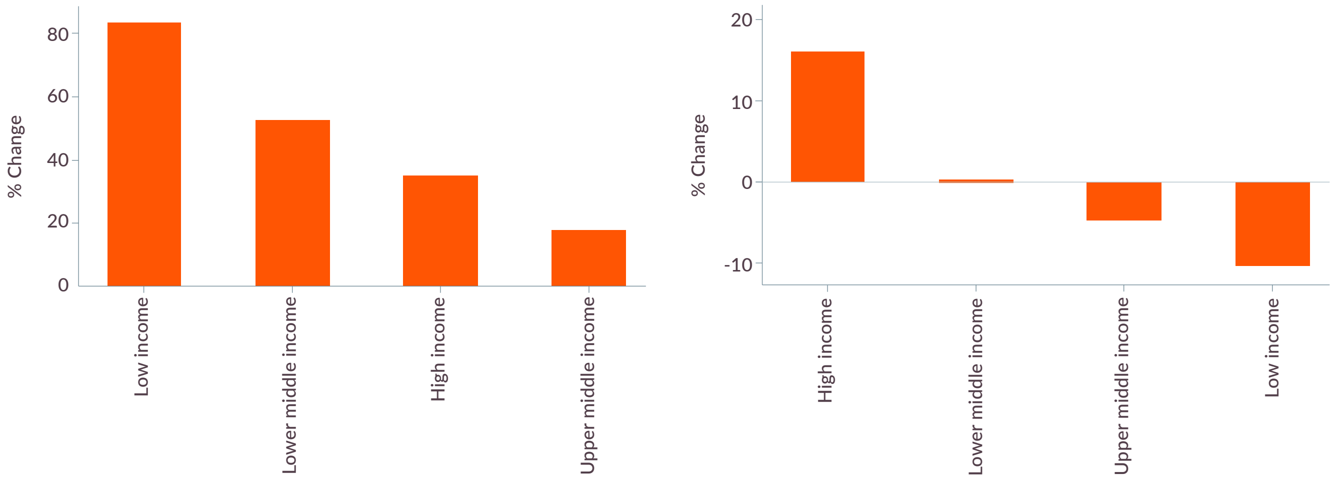
Note: Shares are calculated as a share of total wealth in current US dollars.

Europe and Central Asia have the largest share of gas wealth through time, with notable reserves in Russia. North America also has gas wealth, although this falls to zero as economic rents in both Canada and the United States are estimated to have significantly fallen since 2015. These regional variations in value can lead to different distributions of changes in wealth across regions and countries. These global distributions in wealth are discussed in the next section.

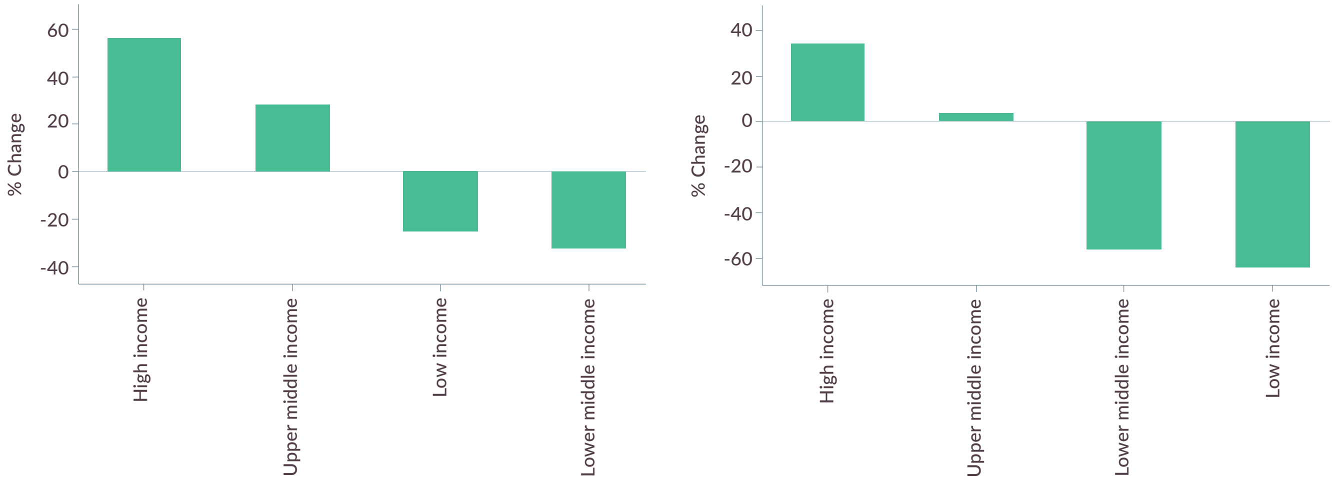
GEOGRAPHIC AND INCOME GROUP DISTRIBUTION OF NONRENEWABLE NATURAL CAPITAL

Assessing the global distribution of nonrenewable natural capital can help us understand which groups of countries and regions are becoming richer in nonrenewable wealth and which are getting poorer. In all income groups, fossil fuel wealth is converging across countries in absolute terms but not in per capita terms (panels a and b in Figure 5.8, respectively).

FIGURE 5.8
Change in fossil fuel and mineral wealth, by income group


Panel a: Change in fossil fuel wealth

Panel b: Change in fossil fuel wealth per capita


Panel c: Change in mineral wealth

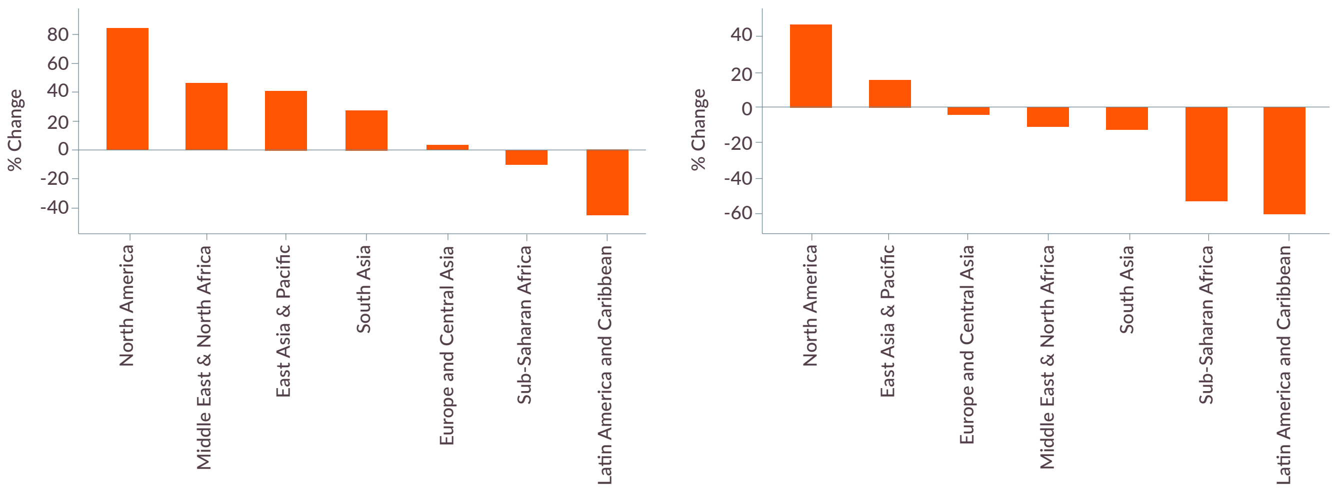
Panel d: Change in mineral wealth per capita

Mineral wealth, on other hand, is diverging, both in terms of absolute levels of wealth and in per capita wealth across income groups (panels c and d in Figure 5.8, respectively), with higher-income countries holding a growing share of mineral wealth between 1995 and 2020. Fossil fuel wealth per capita decreased overall in all regions of the world, other than in North America and in East Asia and the Pacific due to sizable new discoveries and exploitation of proven reserves (see panels a and b in Figure 5.9). However, as discussed previously, this does not mean absolute wealth did not grow in other regions of the world, it just failed to grow at the same pace as population growth. Mineral wealth per capita has been increasing across East Asia and the Pacific and Latin American and the Caribbean, reflecting large increases in proven reserves of metals and minerals. Mineral wealth declined in both per capita and absolute terms in Sub-Saharan Africa.

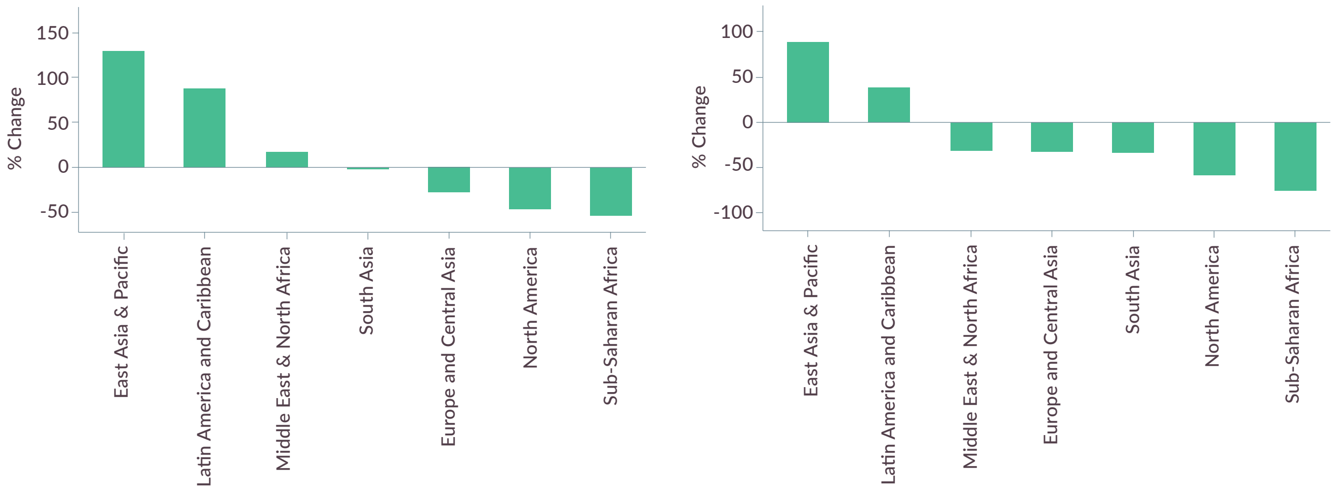
The country-level distribution, as shown in Figure 5.10, clearly indicates where hot spots exist for changes in fossil fuel and mineral wealth per capita. Panel a shows hot spots for fossil fuel wealth per capita in Canada, Kazakhstan, Azerbaijan, and China. For metals and minerals, there have been large declines in wealth per capita across most of Sub-Saharan Africa and North America and Europe.

FIGURE 5.9

Change in fossil fuel and mineral wealth, by region group


Panel a: Change in fossil fuel wealth

Panel b: Change in fossil fuel wealth per capita

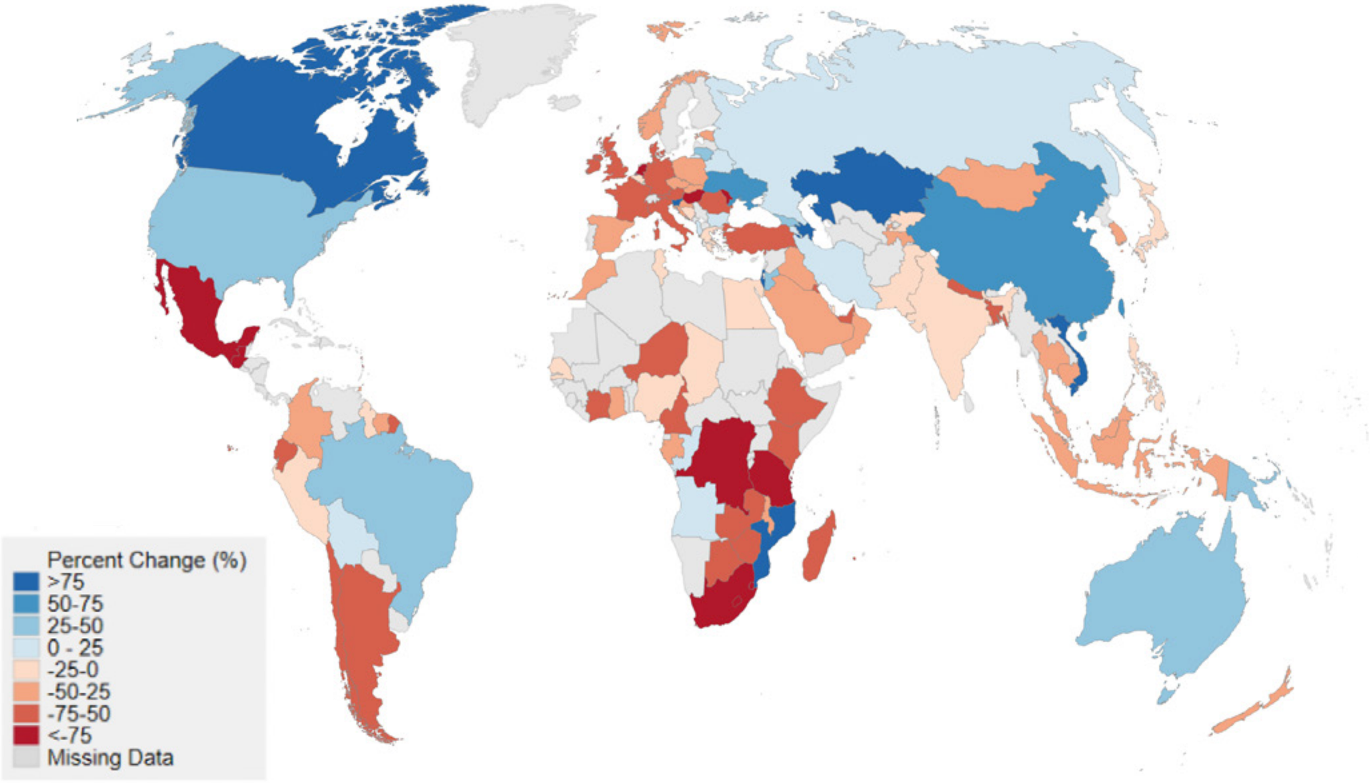

Panel c: Change in mineral wealth

Panel d: Change in mineral wealth per capita

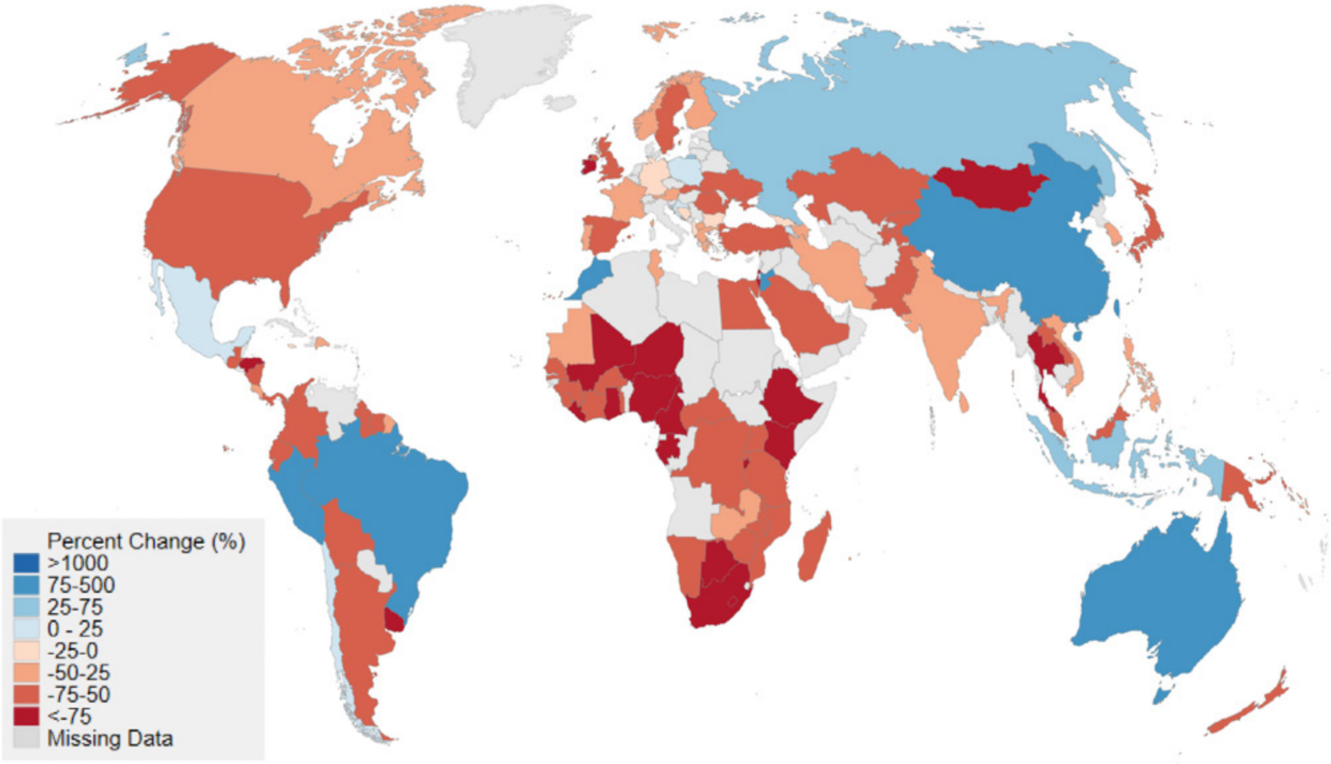
FIGURE 5.10:

Global map of the change in fossil fuel and mineral wealth per capita, 1995 and 2020

Panel a: Fossil fuels



Panel b: Metals and minerals



It clearly shows how the emerging hot spots for mineral wealth per capita are in Latin America, East Asia and the Pacific, parts of Europe and Central Asia (notably Russia), and Australasia. In sum, the global geographic and income distribution of nonrenewable natural capital shows the changing regional dynamics of this type of wealth. Fossil fuel wealth per capita is increasing in many countries across different regions of the world, while mineral wealth per capita is increasing in more concentrated hot spots. Both mineral, and to a lesser extent fossil fuel, wealth per capita is becoming more concentrated in the already richer regions of the world.

SHIFTING COMPOSITION OF NONRENEWABLE NATURAL CAPITAL WEALTH: METALS AND MINERALS

Part of the changing global distribution in nonrenewable assets may be due to the shifting composition of the nonrenewable wealth of nations, including the changing demands for specific primary metals and critical minerals. As the world transitions to a low-carbon economy and the share of energy use shifts from fossil fuels toward renewable energy, similar shifts might be observed in nonrenewable natural capital from fossil fuel wealth to mineral wealth (IEA 2021; World Bank 2017). Proven reserves of fossil fuels may decline as they become uneconomical, while increasing demand for primary metals and critical minerals, such as copper, lithium, and nickel, may make more geological reserves economical and incentivize further exploration. The absence of geological surveys and broader exploitation risks can be further impediments or enablers to new exploration and extraction from the resource base. For example, in the Democratic Republic of Congo, copper exploration starts at a concentration of 1 percent and production has an average concentration of about 2 percent. In Chile, exploration starts at 0.2 percent and production at around 0.5 percent. In the Democratic Republic of Congo, copper is below 1 percent concentration and is therefore left in the ground, leaving foregone minerals for the energy transformation and revenues for the development of the economy.

In this report, data were collected on 13 minerals, including bauxite, cobalt, copper, gold, iron ore, lead, lithium, molybdenum, nickel, phosphate, silver, tin, and zinc. Globally, the wealth per capita of six minerals has increased, while six have been declining.[159] The minerals that increased the most in per capita terms were lithium, nickel, phosphate, and copper, while gold, silver, bauxite, and lead had the biggest declines. One of the main characteristics of mineral wealth, like nonrenewables more broadly, is the year-to-year volatility. There are some notable increases and decreases in wealth per capita, particularly for phosphate, molybdenum, and nickel, and these are likely to reflect either changes in the quantity of proven resources or the accuracy of geological reporting.

The five richest countries in minerals as of 2020 were Australia, Brazil, China, India, and Russia. Most of these countries had general increases across their mineral wealth per capita, with India being the exception, where mineral wealth per capita declined across all metals and minerals (see Figure 5.12). Some of the largest increases were for minerals important to both digital technologies and electric batteries—cobalt and lithium. These minerals had wealth per capita increases in Australia of over 15-fold and 25-fold, respectively, reflecting new proven reserve deposits becoming economical. Lithium wealth per capita also increased nearly 80-fold in Brazil. China, which has a large share of production in many minerals globally,[160] has had significant mineral wealth per capita increases, with both molybdenum and phosphate increasing over 10-fold between 1995 and 2020.

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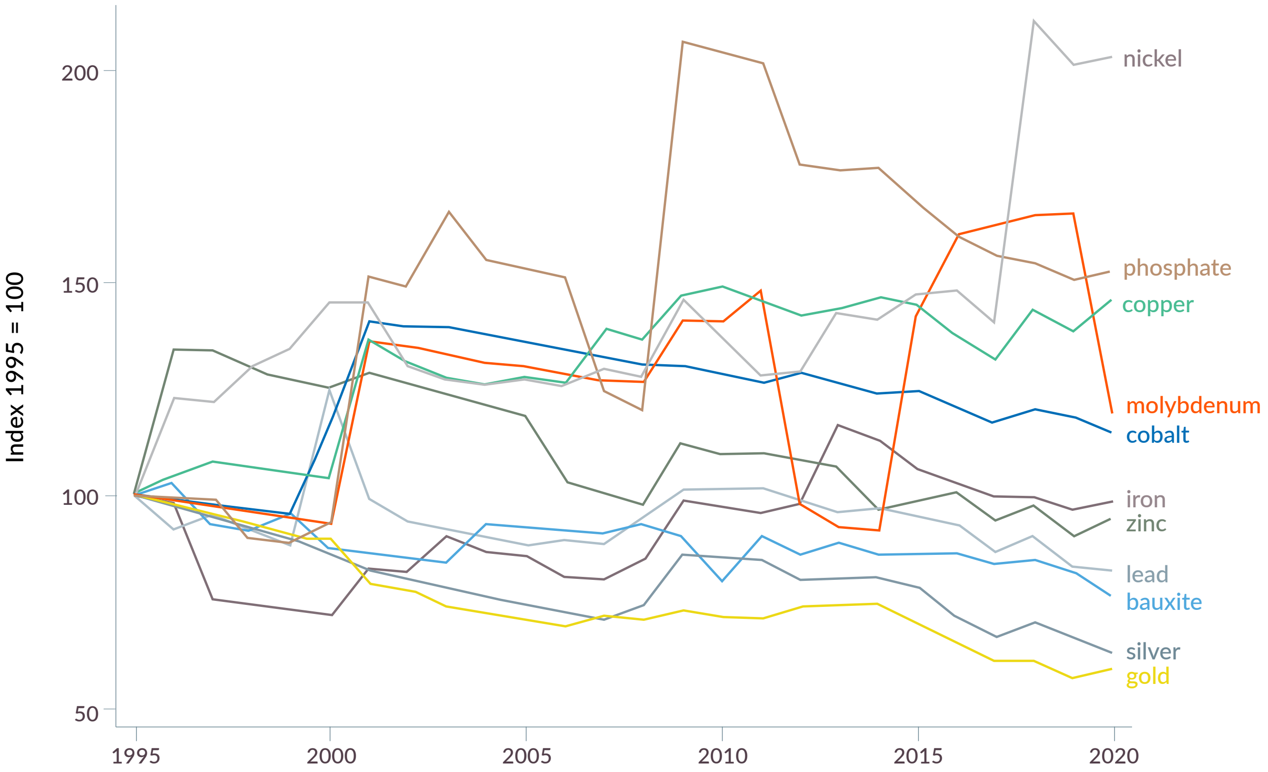
[159] See Figure 5.11.

[160] This has led to several countries' geological agencies investigating their reliance on minerals imported from China. See, for instance, USGS (2020).

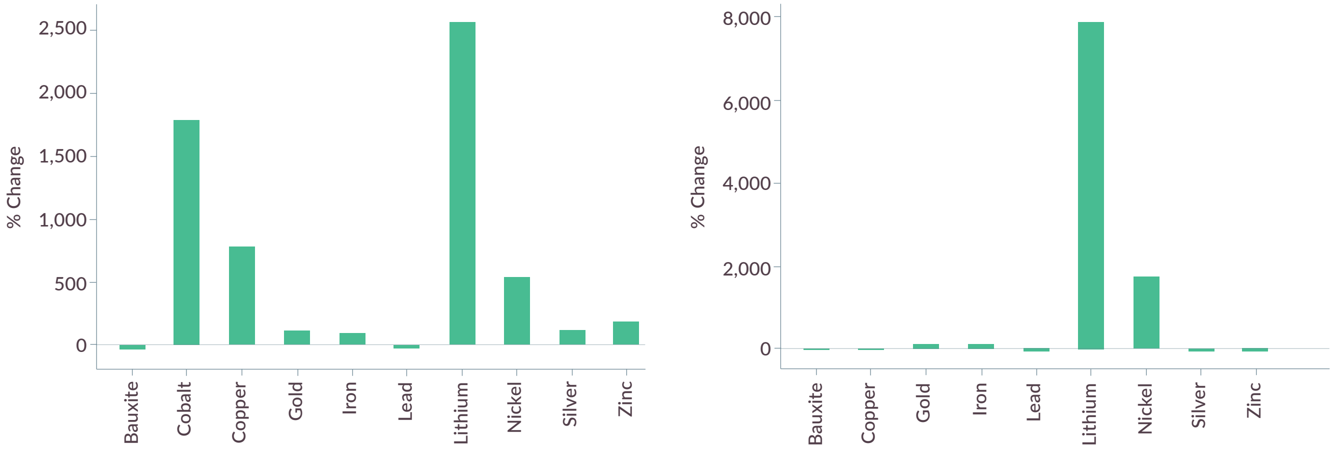
FIGURE 5.11
Global trends in mineral wealth per capita, by selected minerals, 1995–2020



Source: World Bank staff estimates.
Note: Wealth per capita is measured in chained 2019 US dollars. Lithium increased over sevenfold and so could not be shown on this scale. Tin wealth could not be estimated using the volume index due to estimates finding persistently zero resource rents using best available data.

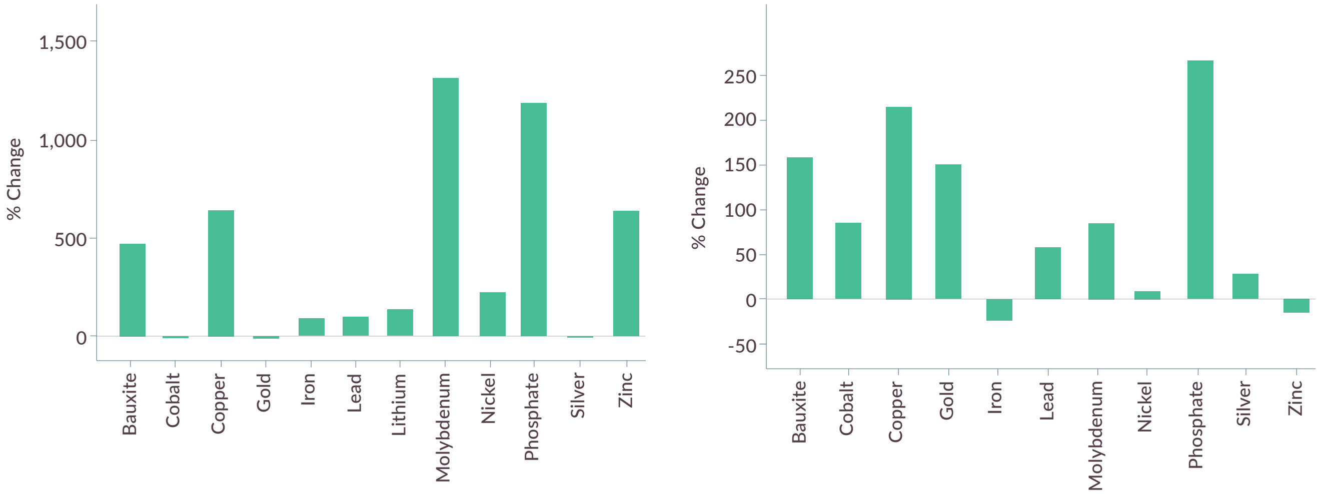
FIGURE 5.12

Percent changes in mineral wealth, selected countries, by mineral, 1995–2020



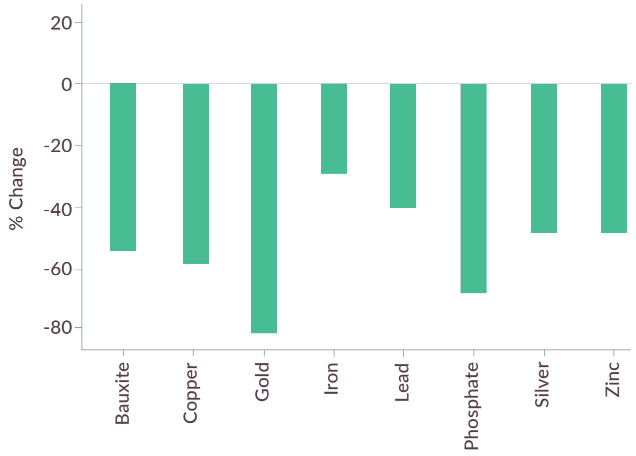
Panel a: Australia

Panel b: Brazil



Panel c: China

Panel d: Russian Federation



Panel e: India

Source: World Bank staff estimates.

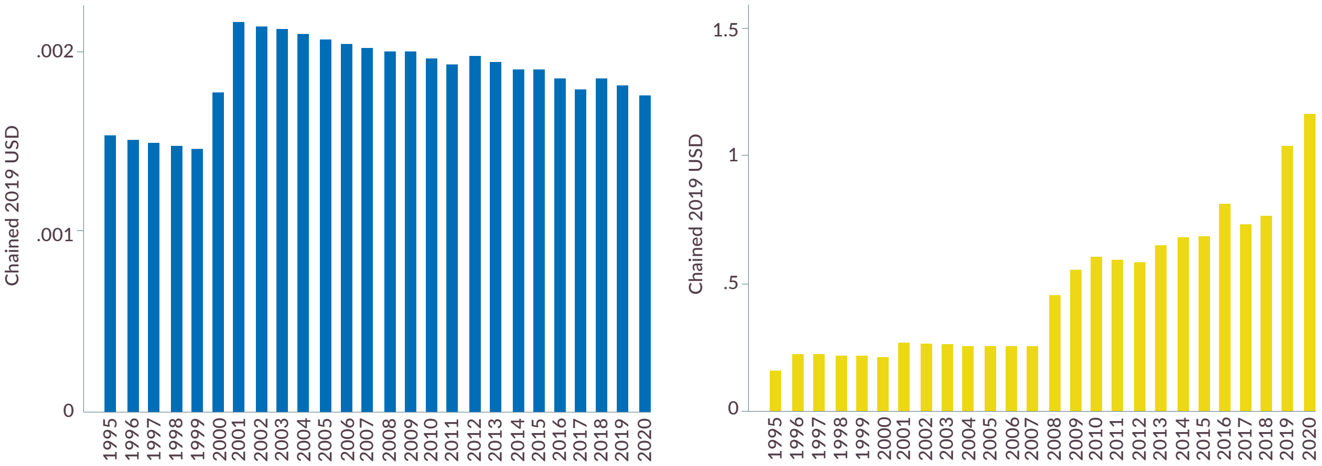
Note: Wealth is measured in chained 2019 US dollars.

NEW CRITICAL MINERALS ADDED IN CWON'S WEALTH ACCOUNTS—COBALT, LITHIUM, AND MOLYBDENUM

As economic production becomes more complex and technologically advanced, the economic use case for minerals expands. To estimate changes in the mineral wealth of nations, it is important to add minerals of notable economic value, where data are available to produce an account. In this version of CWON, the wealth for three new minerals was estimated: cobalt, lithium, and molybdenum. While of high and increasing economic value globally, these minerals are very geographically concentrated. Around 50 percent of the world's proven reserves of cobalt are in the Democratic Republic of Congo, 60 percent of the world's molybdenum proven reserves are in China, and around 10 countries have notable proven reserves for lithium,[161] with the largest shares in Chile (46 percent) and Australia (29 percent). Since 2001, wealth per capita of cobalt has been declining globally, signaling that extraction has increased faster than the discovery or increased viability of proven cobalt reserves (Panel a, Figure 5.13).

FIGURE 5.13

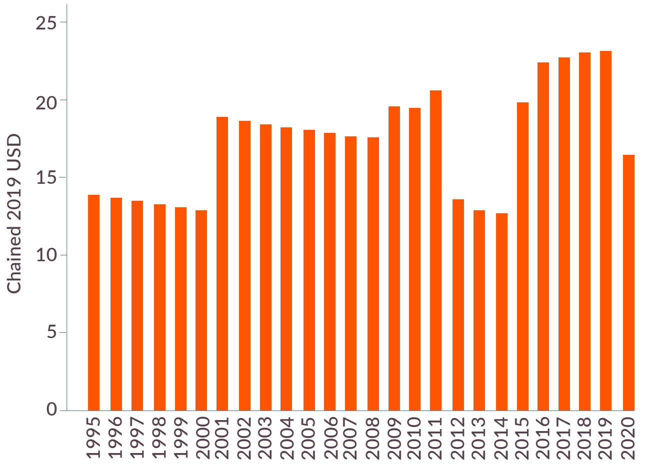
Changes in global wealth per capita for selected minerals: cobalt, lithium, molybdenum



Panel a: Cobalt

Panel b: Lithium

Panel c: Molybdenum



Source: World Bank staff estimates.

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[161] Countries with available data on proven reserves of lithium were Argentina, Australia, Brazil, Chile, the Democratic Republic of Congo, Portugal, the United States, and Zimbabwe.

In contrast, lithium wealth per capita has been increasing, from about $0.2 per capita to $1.2 per capita globally (Panel b, Figure 5.13). Molybdenum wealth per capita has been more volatile, but peaked at over $20 per capita in 2019 and stood at about $16 per capita in 2020 (Panel c, Figure 5.13). As the demand for these critical minerals (particularly cobalt and lithium) increases during the clean energy transition (IEA 2021), it will be important to assess whether these trends continue or change, and what the implications may be for the economic sustainability of countries rich in these resources.

CONCLUSIONS

The new volume-based measure of nonrenewable natural capital per capita has shown that this type of wealth is declining globally. Coal, natural gas, and metals and minerals wealth per capita are in decline, while oil wealth per capita has flatlined over a quarter century. Although nonrenewable natural capital wealth only makes up a small share of total global wealth, it plays a significant role in countries that are rich in subsoil assets. Furthermore, metals and minerals are becoming an increasingly important component in the nonrenewable wealth of nations, with its share of nonrenewable wealth increasing in economic value across all regions. The 10 richest countries in nonrenewable natural capital have almost half of the global value. Critical minerals, including lithium and cobalt, are included on the CWON balance sheet for the first time, and are shown to be increasing in value in per capita terms.

This version of CWON has made several innovations, which have improved the estimation of the nonrenewable wealth of nations. The main innovation has been the switch to a volume-based index, which, particularly for nonrenewable assets, removes most of the effects of commodity price volatility that may distort sustainability assessments. On the other hand, the new volume-based approach makes the series sensitive to data on the proven reserves of resources. This is an important area for future work to improve the coverage and accuracy of proven reserves data.

In addition, while this edition added important minerals to the accounts, there are many more critical minerals and rare earth minerals that are becoming increasingly valuable for their uses in information and communication technologies, transportation, and clean energy production. Although these minerals may also be highly concentrated in specific countries (notably rare earth minerals in China), a future nonrenewable natural capital account may want to add these to the balance sheet.

The data and associated accounts provided here are intended to provide a starting point for further scenario and policy analysis, which would go beyond the scope of this report. With many countries around the world committing to net-zero targets and decarbonization strategies, an interesting avenue for future research would be to assess the extent to which these alter nonrenewable wealth estimates (see Box 5.2). It is possible that a share of proven reserves for fossil fuels are no longer economically viable to extract under such commitments. However, decarbonization strategies would also affect prices, extraction, and use of both fossil fuels and minerals for clean energy, which suggests some countries may have increased nonrenewable natural capital, while others will have less.

BOX 5.2

THE LOW-CARBON TRANSITION AND NONRENEWABLE NATURAL CAPITAL

According to the United Nations Framework Convention on Climate Change (UNFCCC) (2023), global carbon emissions should peak by 2025 at the earliest, then reach net-zero emissions by 2050, and net-zero GHG emissions by the early 2070s to keep to the goal of a 1.5°C temperature increase. Individual countries' pathways to net zero will vary, but globally it implies no further exploration of fossil fuels well ahead of 2030, a global phase-out of unabated coal power generation by 2040, and phasing out all unabated fossil fuels after 2050 (UNFCCC 2023). By the end of 2023, about 80 countries announced net-zero carbon emission pledges through various policy, regulatory, and legal instruments, with deep uncertainty over whether they will be implemented (UNEP 2023; Net Zero Tracker 2024). Should we, then, expect to see declines in nonrenewable natural capital? Furthermore, how much of the current stocks are in fact stranded assets? It is important to stress that pledges and announced targets by themselves do not cause stranded fossil fuel assets or capital gains for minerals. Only implemented and enforced specific policy instruments and market measures, such as taxes, subsidies, cartel actions, or geopolitical decisions can influence market prices and hence rents and recoverable reserves of subsoil assets.

As different countries begin to implement the low-carbon transition, the volatility and uncertainty about future volumes and prices will increase even more. This transition risk (Carney 2015; McGlade and Ekins 2015; Van der Ploeg and Rezai 2019; Mercure et al. 2018) will affect fossil-fuel-producing firms and countries differently depending on their exposed endowments, ability to weather external shocks, and own decarbonization strategies (Peszko et al. 2020). While reduced consumption of fossil fuels would trigger a decline in the global fossil fuel industry, some more resilient producers will experience short- and medium-term increases of their reserves, while others may see an accelerated decline of their subsoil assets (Peszko et al. 2020). The low-carbon transition would also increase the value of climate action minerals.

These effects are likely to translate into different changes in nonrenewable natural capital across space and time. Economic actors aiming to be production leaders during the low-carbon transition pathway may see increases in proven reserves and nonrenewable natural capital as they continue to pursue exploration and discoveries. Whereas those divesting from fossil-fuel-dependent sectors may see their nonrenewable natural capital decline commensurately. Another channel through which decarbonization strategies may affect nonrenewable natural capital wealth is through the weights placed on the different assets in the volume-based index. These weights will increase or decrease in line with rents and the profile of production (that is, bringing production forward or pushing it backwards in time). There may be future cases where increasing weights coincide with declining stocks, which would cause sharp declines in nonrenewable natural capital, or decreasing value coincides with declining stocks, causing muted responses in nonrenewable natural capital.

CWON is not taking any normative position on future price and rent changes but must make some assumptions. The program follows the recommendations of the SNA (2008), SEEA-CF (SEEA-CF, paragraphs 5.133 and 5.134) and SEEA Energy, which state that in the absence of any specific forecasts, future rents are held constant at current-year (2020) values wherever an NPV-RVM approach is used. Given the infinite number of possible future trajectories of rents, and the deep uncertainty about the future policy and market actions related to the low-carbon transition, this is the most neutral and transparent assumption. But it also means that if costs and policies change, the future value of specific nonrenewable natural assets will be different than estimates in this report.

To explore transition risks and the upsides to both fossil fuels and minerals, alternative "what if" scenarios can be simulated with macroeconomic and energy models. Such models should be able to simulate how different real-world policy actions, such as carbon taxes, repurposing of subsidies, tariff and non-tariff trade barriers, or production cuts undertaken by different groups of countries, can influence extraction costs and producer prices of different commodities. The models should also calculate how this would change the volumes of commercially recoverable resources and changes in resource rents for different countries and commodities with respect to CWON's current policy assumptions.

An example of such an analysis of transition risk to future fossil fuel producers is provided in chapter 10 of the CWON 2021 report, conducted with a global computational model, ENVISAGE, modified to estimate transition risks for producers of fossil fuels (Peszko at al. 2021). The analysis found that low-carbon transition policies that can be implemented by fossil fuel importers represent a material risk to the value of all fossil fuel assets. In the 2018–2050 period, global fossil fuel wealth may be $4.4 trillion to $6.2 trillion (13 percent to 18 percent) lower than in the reference scenario, depending on the ambition level of global climate policies. CWON 2021 also calculated the distribution of transition risk across fuels, countries, and asset owners, showing major differences across countries depending on their 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. Level and distribution of stranded assets also differ by policy pathway—whether they are cooperative or not, and whether free riding will meet border carbon adjustment taxes or not.

Where possible, CWON 2024 will make publicly available the final real and nominal wealth estimates, which can be used as inputs for such models and associated statistical code used to derive the wealth estimates. This will enable users and researchers to make their own assessment of likely future scenarios. If simulation models are not available, users of the CWON data will also be able to make much simpler back of the envelope assessments. They can, for example, modify the assumptions about future growth or decline of resource rents used to derive the wealth estimates. Access to the underlying data and codes will not just facilitate users modifying the CWON assumptions to reflect their approaches or questions, but also be valuable as a starting point for researchers wishing to compile comprehensive wealth estimates for individual countries using national, rather than global, data.

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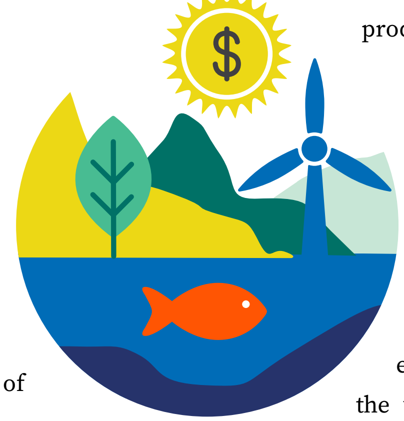
6 Valuation of Hydroelectric Resources

MAIN MESSAGES

- The estimated values of hydroelectric assets are globally consequential. In total, hydroelectric assets were valued at $3.5 trillion (chained 2019 US dollars) in 2020, which is comparable to other renewable natural resource assets. For reference, global fisheries were estimated to be worth $21.8 trillion in 2020, while the corresponding value for global timber assets was $2.8 trillion.
- In China, Brazil, and Canada, hydroelectric assets are also comparable in value to fossil fuel assets. In Paraguay, they represented 47 percent of the country's total natural capital in 2020. Globally, hydroelectric resources represented 23 percent of total energy assets that year.
- Sufficient data are available to value hydroelectric assets in all countries using the method tested in the pilot study of renewable energy asset values in CWON 2021 (Smith et al. 2021).
- East Asia—largely driven by China—was the region with the largest hydroelectric asset wealth in 2020, more than tripling its asset value from 1995. However, when considered in per capita terms, East Asia produced just one-third as much hydroelectric asset wealth as the leading regions (North America and Latin America and the Caribbean).
- Being wealthy in terms of hydroelectric assets does not mean that those assets are exploited to their fullest potential. The United States, which ranked fifth in terms of total hydroelectric asset wealth in 2020, generated just $1.2 million (chained 2019 US dollars) of wealth per installed megawatt (MW) of hydroelectric generating capacity. This was far below the global average of $4.6 million per MW in 2020.
- Estimates of renewable energy asset values beyond hydroelectric assets were not possible due to data limitations. The main hurdle preventing the inclusion of solar and wind assets was the lack of a suitable time series of producer price data for solar/wind producers.



INTRODUCTION

For the first time in the World Bank's comprehensive wealth accounting work, CWON 2021 (World Bank 2021) reported experimental results for the value of renewable energy assets. In that report, estimates of the value of solar, wind, and hydroelectric assets were presented for 15 countries as part of a pilot study to demonstrate the feasibility of their valuation (Smith et al. 2021). The valuation method used in the pilot study was based on an approach where asset values were estimated as the NPV of expected future resource rent. Resource rent, for its part, was estimated as the difference between the revenues realized from exploiting renewable energy resources and the costs of doing so (RVM). This approach is referred to here as NPV-RVM. It is consistent with international guidance on the valuation of natural resources from the United Nations SEEA-CF (United Nations 2012) and SEEA-Energy (United Nations 2019).

This chapter builds on the pilot study results to produce the first global estimates of hydroelectric assets for the CWON database based on NPV-RVM. Though efforts were made to develop global estimates of solar and wind electricity assets, this proved impossible due to limitations in data availability.[162] It remains a goal to present global estimates of solar and wind

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[162] As explained in more detail later in the chapter, the problem resulted from the absence of price data specific to the sale of electricity generated by wind and solar producers.

assets—and other renewable energy assets like geothermal and ocean energy—in subsequent editions of CWON.

Future work should focus not only on the use of renewable energy assets to generate electricity but also on direct heat delivery.

The remainder of this chapter proceeds as follows. First, the rationale for valuing renewable energy assets in CWON is presented. Then the methods and data sources used to value hydroelectric assets in this global study are described in considerable detail.[163] Following this, the results of the global valuation of hydroelectric assets are presented. The chapter ends with a discussion of the results and suggestions for future work.

RATIONALE FOR VALUING HYDROELECTRIC ASSETS

The absence of hydroelectric assets (not to mention solar, wind, and other renewable energy assets) from the CWON natural capital accounts in the past was a concern for assessing the environmental sustainability of economic activity. Since fossil fuel assets have always been included in CWON, there was an imbalance in its treatment of nonrenewable and renewable energy assets. Given the climate-related consequences of fossil fuel use, this imbalance risked sending distorted signals to users of the CWON database regarding the relative economic importance of carbon-intensive, nonrenewable energy sources versus less climate-damaging renewable sources like hydropower. This imbalance is now rectified by treating renewable energy assets, beginning with hydroelectric assets here in CWON 2024, on par with fossil fuels.

The addition of hydroelectric assets to the CWON natural capital accounts (and the eventual addition of other renewable energy assets) is also aligned with recent guidance on the expansion of the 2008 SNA (European Communities et al. 2009) and SEEA-CF asset boundaries. Beginning with the 2025 edition of the SNA, renewable energy assets will be recognized as natural resource assets in the system thanks, in part, to the efforts of the World Bank to develop and test methods for the valuation of renewable energy assets in the CWON 2021 pilot study (Smith and Peszko 2022).[164] The SEEA-CF asset boundary will be similarly expanded at its next update. This places CWON at the frontier of work in this area of emerging importance.

Of course, not all hydroelectric resources qualify as economic assets. In keeping with the general definition of an asset and with the renewable energy specifications of the United Nations Framework Classification for Resources (UNFC; United Nations Economic Commission for Europe 2020),[165] only hydroelectric resources that are viable for use in electricity production under prevailing technological and economic conditions are considered assets here (see Box 6.1 for further details).

Recognizing hydroelectric resources as assets means a method must be found to value them. For CWON 2024, the NPV-RVM approach was adopted, which was first applied to renewable energy assets in the CWON 2021 pilot study (Smith et al. 2021). This method is consistent with guidance in the SEEA-CF and (somewhat less clearly) the SNA, both of which recommend it for valuing natural resource assets in general. In NPV-RVM, asset value is taken to be equal to the present value of the future stream of rent flowing from the resource (SEEA-CF, section 5.4.5). Rent, for its part, is calculated as the difference between resource revenues (less specific subsidies received plus specific taxes paid) and production costs, including returns to labor and produced capital (see annex A4 for further discussion of resource rent).

The validity of NPV-RVM assumes that markets for the generation and sale of renewable energy approximate long-run competitive equilibrium, as only in such markets will the difference between revenues and costs be a reliable guide to estimating resource rent. Markets in many countries—

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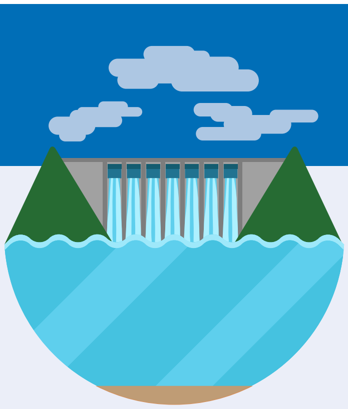
[163] Since this is the first time hydroelectric assets are included in the CWON global accounts, the methods used to value them are presented in greater detail than is the case for the other assets discussed in this report. This is done so that readers will have a clear idea of the approach taken and the rationale for its adoption. Subsequent editions of CWON will not present this same level of detail. Readers interested in details of the concepts and methods applied to valuation of the full suite of CWON assets are referred to the overall methodology report (World Bank 2024).

[164] For further details on endorsed guidance in the SNA update process, see https://unstats.un.org/unsd/nationalaccount/towards2025.asp.

[165] See https://unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/publ/UNFC_ES61_Update_2019.pdf.

BOX 6.1
DEFINITION OF HYDROELECTRIC ASSETS



Following guidance in the UNFC, hydroelectric assets are defined here as resources that are associated with “viable” hydroelectric generation projects. Viable projects are those for which the “environmental-socio-economic viability and technical feasibility has been confirmed” (UNFC, 3). More specifically, economic viability means that:

“Development and operation [of the project] are environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions. All necessary conditions have been met (including relevant permitting and contracts) or there are reasonable expectations that all necessary conditions will be met within a reasonable timeframe and there are no impediments to the delivery of the product to the user or market.” (UNFC, 6)

Technical viability means that:

“Development or operation is currently taking place or, sufficiently detailed studies have been completed to demonstrate the technical feasibility of development and operation. A commitment to develop should have been or will be forthcoming from all parties associated with the project, including governments.” (UNFC, 6)

Based on this, only hydroelectric resources associated with currently existing and operating hydroelectric generation plants or with plants that are well advanced in planning and development qualify as hydroelectric assets. Hydroelectric resources that exist at sites where hydroelectric generation plants do not currently exist and none are well advanced in planning do not qualify as assets and are not within the scope of CWON’s natural capital accounts. This treatment of hydroelectric resources is consistent with the treatment of other natural resources in the SNA and SEEA-CF. For example, the SNA and SEEA-CF recognize timber in a forest (another renewable resource) as an asset only in instances where that timber may be commercially logged at a profit under existing technological and economic conditions. Remote forests with no potential for logging do not qualify as timber assets.[166]

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[166] Similar criteria are applied to defining other renewable and nonrenewable natural resources as assets in the SNA and SEEA-CF as well as in CWON.

especially in the developing world—do not meet this standard because governments intervene in markets (through production subsidies, for example).

Data from the OECD's Product Market Regulation Indicators suggest a movement toward competitive generation since the beginning of the deregulation of electricity markets, at least in developed countries. According to World Bank analysis (Foster and Rana 2020), only a handful of developing countries have, however, implemented liberalized power market models with fully competitive private power generation. Across the developing world, reforms have resulted in hybrid models in which elements of market orientation coexist with continued state dominance of the sector. On top of this, within the OECD, emerging markets and developing countries alike still subsidize renewable energy production and consumption, especially nascent renewable energy technologies, like solar and wind. This poses a theoretical challenge to RVM and a practical measurement challenge because subsidy data are rarely comprehensive and transparent.

For mature renewable energy technologies such as hydroelectricity, however, factor markets can be assumed to be close to long-run competitive equilibrium, even in countries where wholesale electricity markets have not been fully liberalized. Marked heterogeneity and scarcity among sites for hydropower implies that hydro projects should earn both Ricardian and scarcity rents (see the annex to this chapter for rent definitions). Where equilibrium can reasonably be assumed, quasi-rents should not exist. In countries where electricity prices remain regulated and where hydroelectric power utilities remain publicly owned, the assumption of market equilibrium may not hold. Ricardian and scarcity rents will still arise, but they will be captured by electricity consumers rather than by the owner of the resource (government) and their measurement is made more difficult. Most large reservoirs also serve multiple purposes and the revenue from electricity generation is often constrained by the needs of flood control, irrigation, residential/industrial water supply, or recreation. Rents arising from these uses of reservoirs may be captured by various economic actors. The purpose of this study is not to value these other uses, however, but only the use of the reservoirs for generating hydroelectricity.

Despite the challenges posed by energy market regulation, a strong rationale for adopting NPV-RVM is found in the benefits of methodological consistency. The method is widely applied to natural asset valuation in country practice, including in CWON and by UNEP.[167] Users of CWON can evaluate hydroelectric asset values against other natural assets and the assets of the broader comprehensive wealth portfolio. Thus, consistency in valuation across assets is of considerable importance.

METHODS AND DATA SOURCES FOR VALUING HYDROELECTRIC ASSETS

Estimates of hydroelectric asset values for all countries were prepared using NPV-RVM, where either (i) hydroelectric generation accounted for more than 5 percent of total national generation in 2020, or (ii) total installed hydroelectric

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[167] See UNEP's Inclusive Wealth series of reports (UNU–IHDP and UNEP 2012; UNU–IHDP and UNEP 2014; Managi and Kumar 2018; UNEP 2023).

[168] These restrictions were introduced to ensure that countries included in the study would have markets for hydroelectric generation sufficiently well established for the global data used in this study to reflect conditions in the country.

Estimating hydroelectric resource rent and asset value

HYDROELECTRIC RESOURCE RENT

Equation 1 expresses the version of the RVM used to estimate rent for hydroelectric assets in a given country and year t.

$$RR_t^{hydro} = TR_t^{hydro} - O\&M_t^{hydro} - (rK_t^{hydro} + \delta^{hydro}) \qquad (1)$$

where:

RR_t^{hydro} = the residual value estimate of hydroelectric resource rent in year t in the country in question

TR_t^{hydro} = total revenue from sales of electricity generated at so-called “renewable” hydroelectric plants[169] in year t in the country, including any subsidies paid on generation

$O\&M_t^{hydro}$ = cost for labor, materials, fuel, and other supplies to operate and maintain the produced assets (that is, the dams or other civil infrastructure required to create reservoirs plus the hydraulic turbines and other equipment needed to generate electricity and transfer it from the hydroelectric station to the local power grid) used to generate hydroelectricity in year t in the country

r = the economy-wide average annual rate of return to produced capital in the country (a constant)

K_t^{hydro} = the total value of produced capital used to generate hydroelectricity in year t in the country

δ^{hydro} = the annual rate of depreciation of the produced capital used to generatehydroelectricity in the country (a constant).

It must be stressed that RR_t^{hydro} is the rent attributable to the hydroelectric resource itself as a form of natural capital; that is, it is the return to nature in the generation process as opposed to the return to the produced capital used to generate the electricity (such as dams, turbines, or generators). In the RVM formula, the rent attributable to the hydroelectric resource is the residual left over after full costs of converting the flowing water to useful electricity—including an estimate of the normal profit for the producer—are deducted.

A NOTE ON SUBSIDIES AND TAXES

In general, when estimating rent on natural assets, including hydroelectric assets, it is recommended to exclude subsidies on production[170] from the estimation and add taxes on production (SEEA-CF, section 5.4.5). Subsidies play a particularly important role in promoting new renewable energy generation, such as solar and wind. Consequently, equation 1 should be written as:

$$RR_t^{hydro} = TR_t^{hydro} - O\&M_t^{hydro} - subsidies^{hydro} - (rK_t^{hydro} + \delta^{hydro})$$

where $subsidies^{hydro}$ is an estimate of the subsidies received by hydroelectric producers. Subsidies might come in any of several forms:

- Subsidies paid directly on production; for example, a subsidy paid to electricity producers per unit of electricity generated.
- Indirect subsidies that reduce costs of production but are not directly related to it; for example, an increased capital consumption allowance rate permitting producers to write investments in certain kinds of produced assets off more quickly than normal.

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[169] Renewable hydroelectric plants are those where water flows through the hydraulic turbines only because of natural forces. These contrast with so-called “pumped storage” plants where the water flowing through the turbines is pumped from a lower reservoir below the turbines back into an upper reservoir to be used again. This pumping usually occurs at night when demand for electric power is low and excess power is therefore available from non-hydro sources. Pumped storage plants were not considered in this study. So-called “mixed” plants are those which include some pumped storage capabilities along with renewable generation. For the purposes here, mixed plants were considered renewable.

[170] In some countries, subsidies are also paid on consumption; for example, many governments artificially lower the price of gasoline or electricity by providing households with direct payments that offset some of their spending on these goods or by holding the producer prices of these goods artificially low. Depending on the nature of these consumption subsidy schemes, and how they impact producer process and revenues, they too might have to be taken account of in estimating resource rent. If, for example, the revenue earned by hydroelectric generators, TR_t^{hydro}, was derived using price data that reflect subsidized household prices, then that revenue estimate will be too low by an amount equal to the consumption subsidy. In that case, the value of the consumption subsidy would have to be added back in the estimation of resource rent. Furthermore, countries that subsidize household energy consumers often also compensate producers for their foregone revenues through explicit or implicit production subsidies, such as fiscal transfers, tax breaks, or higher charges to industrial and commercial end users.

Subsidies on production should be deducted when estimating rent as they increase net revenue from resource exploitation (either directly in the case of those paid on production volumes or indirectly for those that reduce production costs) and, by consequence, increase resource rent derived via RVM. Since subsidies do not represent a return to nature, they should be excluded from resource rent.

In practice, data on subsidies paid to natural resource companies are difficult to obtain (especially data on indirect and implicit subsidies), so subsidies are generally not accounted for by statistical agencies when they are compiling official national estimates of resource asset values.[171] This is the case in the estimation of rents on fossil fuel assets, for which detailed data on subsidies by country and type of production are unavailable.

According to the SNA and SEEA-CF, subsidies paid by governments to support natural resource production should be accounted for; that is, deducted from revenues in the calculation of resource rent. In practice, however, it is difficult to know to what extent estimates of hydroelectric asset values do include subsidies paid on hydroelectricity generation or consumption. Direct subsidies paid to producers may be missed because they are unlikely to be reflected in end-user electricity prices, and, as explained later, the methodology used here relies on residential end-user prices for estimating producers' revenues and hydroelectric resource rent.

Indeed, this shortcoming was the main reason why solar and wind assets could not be included in the study, since direct subsidies on production (for example, feed-in-tariffs) play a more important role in solar and wind producers' revenues than for hydroelectric producers. Deeper understanding of the extent to which the NPV-RVM valuation approach taken here—indeed, taken in the case of any of the natural assets included in CWON—would require further study. For this reason, subsidies are not accounted for in the valuation of hydroelectric assets, which is consistent with all other CWON assets.

FROM RENT TO RESOURCE VALUE

With hydroelectric rent estimated following equation 1 for each country and year between 1995 and 2020, the next step was to determine the expected pattern of future rents for the NPV calculation. This required decisions regarding two parameters: the level of rent in future years and the number of years for which rent will flow. Regarding the latter, it was assumed rent will flow for 100 years—in keeping with the assumption used in the valuation of other renewable natural resource assets in CWON. As for the former, in keeping with the general approach to renewable natural resource asset valuation in CWON and in the SEEA-CF (SEEA-CF, paragraph 5.133), it is assumed that future hydroelectric rents will be equal to the rent observed in the period in question. For example, to value hydroelectric assets for 2020, a 100-year series of rental incomes is assumed equal to the estimated 2020 rent in the NPV calculation.

With the current rent and its expected future pattern determined, estimation of the value of hydroelectric assets in each country proceeded according to equation 2.

$$2)\quad V_t^{hydro} = \sum_{n=1}^{100} \frac{RR_t^{hydro}}{(1+r_g)^n}$$

where:

V_t^{hydro} = the value of hydroelectric assets in year t in the country

RR_t^{hydro} = the resource rent accruing to hydroelectric assets in year t (as defined in equation 1 and including subsidies) in the country

T = hydroelectric asset life in years (assumed to be 100 years in all countries)

n = future periods from 1 to 100

r_g = economy-wide discount rate (assumed, following CWON convention, to be 4 percent for all countries and years).

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[171] For example, Statistics Canada's estimates of Canada's oil assets do not account for subsidies. The same is true of the United Kingdom, Australia, Norway, and other countries. CWON's approach of not considering subsidies for these assets is thus aligned with official statistical practice, if not with international statistical guidance.

Data sources and assumptions

REVENUES FROM ELECTRICITY GENERATION

Two data points were required to estimate revenues from hydroelectricity generation (TR_t^{hydro} from equation 1):

- The quantity of hydroelectricity generated
- The price received by hydroelectric power producers in each country and year.

Obtaining global data on generated quantities of hydroelectricity is relatively straightforward. The International Renewable Energy Agency (IRENA) provides these data annually for most countries in the world going back to 2000.[172] The UN provides similar data covering the period back to the 1990s through its Energy Statistics Database.[173] The generation data used in this study were derived from a combination of these two sources. In general, the two sources agreed exactly on generation figures for a given country and year. Where they did not, a simple average of the data from the two sources was used unless there was clear reason to prefer the figure from one over the other.

Obtaining data on the average annual prices received by hydroelectric power producers ("producer prices" hereafter) at the country level proved more difficult, as no globally complete database of producer prices exists from public or private data suppliers. Preparing such a database would be challenging given the difficulties of estimating annual prices when energy markets in countries with competitive wholesale electricity markets today include pricing mechanisms that adjust to demand and supply on an hourly basis. In addition, in competitive, regulated, and hybrid electricity market models there are multiple mechanisms for generating revenues by power producers. Besides electricity, electricity producers also sell capacity readiness and other ancillary services that system operators buy to maintain grid stability and security.

Given the lack of a global database, producer prices were estimated indirectly. This was done starting with the only available database of electricity prices close to global coverage, the IEA's Energy Prices database.[174] This database, which is only available by paid subscription, contains weekly, monthly, quarterly, and annual end-user (residential, commercial, and industrial) electricity prices in nominal local currency units (LCUs) for 140 countries from 1970 to 2022. Since the most complete country coverage in this database was for annual residential end-user prices, those prices (adjusted to account for delivery charges and other non-production costs—see below) were chosen as the basis for estimating the annual producer prices required for this study. For countries not covered by the IEA database, regional average residential electricity prices were calculated and used as a proxy for national prices. For countries included in the IEA database but with data missing for certain years, missing data were estimated from the available data using either backward or forward linear extrapolation.

To estimate producer prices in each country, IEA residential prices were multiplied by a time-invariant conversion factor that reflects the share of the price expected to be received by hydroelectric producers. These conversion factors were determined empirically for the individual countries listed in Table 6.1 by identifying factors that, when applied to the IEA residential electricity price data, resulted in figures that best matched the electricity prices used for the country in question in the pilot CWON study of renewable energy assets (Smith et al. 2021). The prices used in the pilot study are considered accurate because they were derived from country-level electricity market data. In determining these country-specific factors, priority was given to finding factors that resulted in prices that best matched pilot study prices for recent years. For countries not included in the pilot study, another approach to determining the conversion was required.

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[172] See https://pxweb.irena.org/pxweb/en/IRENASTAT?_gl=1*1djkx00*_ga*MTM2ODIxMzA0Mi4xNjk4NjkyMjYx*_ga_7W6ZEF19K4*MTY5ODY5MjI2MC4xLjEuMTY5ODY5MjU0Mi42MC4wLjA.

[173] See http://data.un.org/Data.aspx?d=EDATA&f=cmID%3aEC.

[174] See https://www.iea.org/data-and-statistics/data-product/energy-prices#overview.

TABLE 6.1

Residential-to-producer price conversion factors by country/region

COUNTRY/REGION	RESIDENTIAL-TO-PRODUCER PRICE CONVERSION FACTOR
Canada	0.6
United States	0.28
Australia	0.25
Brazil	0.5
China	0.72
Japan	0.46
Russian Federation	0.5
Türkiye	0.6
India	0.9
Europe and Central Asia region (western and central European countries)	0.25
Europe and Central Asia region (other than western and central European countries)	0.61
Rest of world, competitive markets	0.61
Rest of world, non-competitive markets	0.8

Source: World Bank staff estimates.

For countries in western and central Europe, the factor (0.25) was similarly chosen to best match the prices used in the pilot study for other European countries (France, Germany, Italy, Spain, Sweden, and the UK). For all other countries with a competitive electricity market according to the World Bank's Global Power Markets Structure Database (Akcura, forthcoming), the average conversion factor (0.61) of the countries listed in Table 6.1 was used, weighted by each country's share of the combined 2020 hydroelectricity generation. This factor implies that transmission and distribution charges and trader/supplier margins, on average, account for 39 percent of residential prices. Finally, for other countries deemed not to have competitive electricity markets, the factor was set to 0.8, based on expert judgement. This value was chosen to reflect the likelihood of government subsidization of residential prices in these countries, with households paying capped electricity prices close to what power producers themselves receive.

As a test of the reasonableness of the above approach, price data from a commercial database from the Energy Regulators Regional Association (ERRA) were analyzed.[175] Although the ERRA database covers only 44 countries and is missing many values, it does offer reasonable coverage of residential and producer prices for electricity at the country level on a quarterly basis for the period 1999 to 2022.

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[175] See https://erranet.org/erra-tariff-database/.

An analysis of the ratio of producer to residential prices in this database suggests that the ratio of 0.61 applied to most countries in this study is appropriate. For the period and countries covered by the ERRA database, the average ratio of producer to residential prices was 0.58. These countries are, for the most part, like those to which the factor of 0.61 was applied; that is, lower- or middle-income countries.

This approach to converting residential prices to producer prices is pragmatic but has several limitations. First, the assumption of a time-invariant relationship between residential and producer prices within a given country is unlikely to be held in practice. For example, assuming time-invariance implies that electricity transmission/distribution providers are affected equivalently to electricity generators when residential electricity prices change, which is not necessarily the case. It is more likely that generators and transmission/distribution providers will be affected differently by price changes. Such nuances could not be approximated in the study due to the unavailability of a comprehensive global electricity producer price database. Second, the assumption that the same time-invariant ratio can be applied across countries is a simplification. For example, a lower ratio should be expected in large and sparsely populated countries, where transmission and distribution costs are a larger share of consumer prices. Still, until a global database of producer prices is compiled, these pragmatic assumptions are the most robust available way to proceed with the estimation. This is discussed further in the final section of the chapter on future work.

Following the estimation of producer prices in LCUs for all countries, conversion from LCUs to US dollars was accomplished using the market exchange rate of the reference year (that is, prices in 1995 LCUs were converted to US dollars by applying the 1995 LCU to the US dollar market exchange rate, obtained from the World Bank World Development Indicators database).[176] Finally, total annual revenues from sales of hydroelectric power by country (TR_t^{hydro}) were obtained by multiplying estimated hydroelectric generation by the estimated producer price for each country and year.

Costs of electricity generation

Hydroelectricity generation costs are of two types, both of which had to be estimated indirectly.

- **User costs of capital:** The annual costs of employing the hydroelectric power plant (including the dam and any other civil works) in the production process (δ^{hydro} in equation 1), comprising the expected annual return to the owner of the power plant plus the annual cost of depreciation of the power plant (the δ^{hydro} variable in equation 1).
- **Operating and maintenance costs:** The annual expenses required to operate and maintain the power plant, including labor, materials, fuel, and other supplies (K_t^{hydro} in equation 1).

CAPITAL COSTS

As with electricity prices, no global database of country-level capital costs for hydro generation exists. The closest to this is a set of regional investment cost estimates available from IRENA as part of its annual report on costs of renewable energy generation (IRENA 2023).[177] IRENA presents these estimates as regional averages for two periods (2010–2015 and 2016–2021),[178] with separate estimates for the costs of installing large and small hydro plants. To render these capital cost data suitable for use in the study, it was necessary first to extend them to cover the full period (1995–2020)[179] and then to convert the figures from constant US dollars to nominal US dollars using the implicit GDP price deflator for the United States.[180]

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[176] See https://databank.worldbank.org/source/world-development-indicators.

[177] See https://www.irena.org/Publications/2023/Aug/Renewable-Power-Generation-Costs-in-2022#.

[178] IRENA's regional breakdown is Asia, Africa, Central America and the Caribbean, Eurasia, Europe, the Middle East, North America, Oceania, and South America. In addition to these regions, the IRENA capital investment cost data provide specific estimates for three countries: Brazil, China, and India.

[179] Annual values for the IRENA capital costs were estimated as follows: annual investment costs during the 2010–2015 period were assumed equal to IRENA's 2010–2015 average investment cost value, for the 2016–2020 period they were assumed equal to IRENA's 2016–2021 average value, and annual investment costs prior to 2010 were assumed equal to the average of IRENA's 2010–2015 and 2016–2021 values.

[180] This approach parallels that used by IRENA to derive the constant price values (IRENA, pers. comm.).

With an annual time series of nominal capital investment costs from 1995 to 2020 by country in hand, the next task was to create a time series of values of the produced capital stocks used in hydroelectric generation in each country (K_t^{hydro}). Estimating K_t^{hydro} was complicated by the fact that considerable investment in hydroelectric generation infrastructure took place before 1995 in almost all countries. Therefore, an estimate was required of the 1994 produced capital stock value for each country before the 1995–2020 time series could be compiled. The 1994 estimate was derived by applying an approach outlined in the OECD manual on measuring capital stocks (OECD 2009, section 15.7). According to that approach, a reasonable estimate of the stock of produced capital in any base year may be derived by dividing the value of investment in the base year by the sum of the capital's deprecation rate plus the long-term growth rate of real GDP in the country in question. Equation 3 expresses this approach to estimating base year stocks of hydroelectric power plant produced capital stocks.

3) $$K_0^{hydro} = \frac{I_0^{hydro}}{\delta^{hydro} + \theta}$$

where:

K_0^{hydro} is the value of the produced capital stock used for hydroelectric generation in the base year (1994 in all but a few cases[181]) in each country

I_0^{hydro} is the value of investment in produced capital used for hydroelectric generation in the base year in the country

δ^{hydro} is the annual rate of depreciation of produced capital used for hydroelectric generation (a constant of 1.67 percent in all countries and years based on the assumption that hydroelectric-generating dams and equipment have universal 60-year service lives)

θ is the long-term annual growth of real GDP in the country, derived from World Bank data.

The main missing piece of information in equation 3 was the value of investment, I_0^{hydro}, which had to be separately estimated. The installed hydroelectric generation capacity in each country in 1994 was divided by the assumed age of the oldest hydroelectric plants in the country[182] to derive an estimate of the annual average quantity of capacity additions over the history of the country's hydroelectric power industry. This quantity was taken to be the addition of new capacity in 1994, which was then multiplied by the estimated 1994 investment cost derived from the IRENA data to estimate the value of I_0^{hydro} in nominal US dollars.

Once K_0^{hydro} was estimated, an annual time series of hydroelectric produced capital stocks (nominal US dollars) from 1995 to 2020 for each country was estimated using a standard perpetual inventory method approach. That is, produced capital investment was added in each year to the previous year's stock value and depreciation was deducted. The value of investment in each year was then calculated by multiplying the newly installed hydroelectric generating capacity in that year[183] by that year's estimated value of capital investment costs per unit of installed capacity (in MW).

OPERATING AND MAINTENANCE COSTS

In addition to providing estimates of capital investment costs by region, the IRENA renewable energy cost report (IRENA 2023) provides estimates of operating and maintenance costs for hydroelectric plants. These estimates are highly generalized, however, with IRENA simply reporting that, on average, operating and maintenance costs at hydroelectric plants can be assumed to be around 2 percent of the capital cost of the installed produced capital. In the absence of a better estimate, this figure was applied uniformly to all countries and years.

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[181] Four countries had no installed capacity for hydroelectric generation in 1995: Belize, Cambodia, Liberia, and Sierra Leone. For these countries, the value of produced capital stocks used in hydroelectric generation were simply estimated by cumulating the net investment in produced capital beginning in whatever year the country's hydroelectric generation began.

[182] This age was taken to be 50 years in all countries except Brazil, India and those in North America, Eurasia, Europe, North America, and Oceania, where it was assumed to be 75 years.

[183] The newly installed hydroelectric generating capacity was calculated as the difference between the opening and closing stock of installed generating capacity in the year.

Estimating rent and asset values

With estimates of the revenues generated from hydroelectric generation and the associated capital and operating and maintenance costs in hand, it was straightforward to estimate the rent attributable to hydroelectric assets in each country and year using equation 1. The only additional variable required was r, the economy-wide average annual rate of return to produced assets. Ideally, country-specific values of r would have been used, but such rates are not readily available. The following annual rates were assumed instead (intended to reflect real returns): 4 percent in Europe, North America, and Oceania; 8 percent in Africa, Central America and the Caribbean, Eurasia, the Middle East, and Latin America; and 10 percent in Asia. These are the same rates as those used in the pilot study.[184] Once the hydro resource rent was estimated, the final step was to calculate the value of hydroelectric assets as the present value of future rents over the assumed lifetime of hydroelectric assets (100 years) using equation 2.

In certain instances, the value of RR_t^{hydro} dropped below zero in a given country and year due to temporary situations with respect to electricity prices or electricity generation levels, both of which fluctuate over time. In those instances, the value of V_t^{hydro} was set to zero.

ESTIMATING HYDROELECTRIC ASSET VALUES IN REAL TERMS

In the past, CWON presented asset values in real terms by deflating nominal asset values using an economy-wide GDP implicit price deflator for each country. This practice has been replaced in the 2024 edition with a volume index (see chapter 2 for further details). Volume indexes offer estimates of real asset values that better reflect the role assets play in production processes, which is central to the assessment of sustainability. Deflation using a price index is appropriate when the role assets play as stores of value to fund future consumption is the key issue. As explained in chapter 2, this is only in the case of financial assets.

To produce the real value of hydroelectric assets in chained 2019 US dollars following the approach outlined in chapter 2, a physical volume measure was needed to represent the quantity of hydroelectric assets available at any given time in each country. The quantity of electricity generated annually in a country measured in megawatt hours was chosen as the physical volume measure.[185] An alternative could have been the installed generating capacity measured in MW to represent the physical volume. This was rejected because the installed capacity fails to capture the actual volumes of valuable electricity generated due to the different operational priorities of multifunctional reservoirs. Furthermore, changes in generated quantities over time implicitly capture quality changes in both the hydroelectric asset and the produced assets used to capture it, which is a desirable feature for the volume index. Due to aging of equipment and environmental factors such as sedimentation of reservoirs (Schellenberg et al. 2017), there tends to be a reduction in the capacity use factor of a given hydroelectric plant to generate electricity over time. Moreover, the changing climate is affecting the availability of water resources in varying ways across the planet, meaning that previous generation levels may become difficult to maintain due to declining water availability.[186] The next section presents the results in more detail.

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[184] Making assumptions regarding these rates is less than ideal. However, the impact on the overall results is muted by the fact that the expected returns to produced assets do not have a large bearing on the value of resource rent. For example, reducing the assumed rate of return on produced assets by 25 percent (from 4 percent to 3 percent) for Canada increases the 2020 estimate of hydroelectric resource value by just 7 percent.

[185] In the case of a single, homogenous asset like hydroelectric assets, changes in the volume index over time are driven entirely by changes in the physical quantity of the asset (in this case, by changes in the quantity of hydroelectricity generated over time). Expressing those changes in chained 2019 US dollars is merely a matter of presentation, done to put the changes in terms that are more familiar in an economic context. Changes in the prices of hydroelectric assets relative to other assets do, however, come into play when those assets are aggregated with other assets into the broader volume indexes of natural capital and, ultimately, comprehensive wealth presented in this report (see chapter 2 for details). In those indexes, changes in hydroelectric assets will figure more or less prominently in changes in the broader indexes, depending on whether hydroelectric assets increase or decrease in value relative to other assets over time.

[186] This is happening, for example, in the Colorado River basin of the United States, where the Hoover Dam is less and less capable of generating electricity to its full potential because of reduced water levels in its reservoir, Lake Mead. (NASA, no date. See https://earthobservatory.nasa.gov images/150111/lake-mead-keeps-dropping.)

HYDROELECTRIC ASSET VALUES

Table 6.2 compares hydroelectric asset values in chained 2019 US dollars for 1995 and 2020 for World Bank country regions and shows significant changes in the regional pattern over time. Latin America and the Caribbean was the region with the greatest hydroelectric asset value in 1995, due mainly to Brazil, which had the largest hydroelectric asset value of any country in 1995 (Table 6.3). The regions of East Asia and the Pacific, Europe and Central Asia, and North America also had large values in 1995. By 2020, the regional picture had changed considerably, however, with East Asia and the Pacific more than tripling its 1995 asset value to gain the top spot by a small margin over Latin America and the Caribbean. Except for Europe and Central Asia and North America, other regions saw substantial growth in value over the period as well. The lack of growth in Europe and Central Asia and North America reflects the maturity of the hydroelectric power industries in those regions and the relative lack of suitable sites for continued expansion.

Table 6.2 also presents data on the installed hydroelectric generating capacity and electricity generation by region along with a related variable known as capacity factor, a measure of generation efficacy (Bolson et al. 2022; Prado Jr. and Berg 2011).[187] Looking at weighted average capacity factors by region, Sub-Saharan Africa emerges as the leader, being the only region to improve its factor significantly from 1995 to 2020,[188] and one of only two regions to exceed the global average. In Latin America and the Caribbean, where the capacity factor was greatest in 1995, the 2020 factor was only 80 percent of the 1995 level. Declines in other regions were also considerable. Reasons for declines in capacity may include aging of generating equipment and dams, insufficient investment in repairs and maintenance, and reduced water flow due to climatic factors or sedimentation of reservoirs. Surprisingly, East Asia and the Pacific did not see a significant increase in its capacity factor despite more than quadrupling its installed capacity. A significant addition of new capacity would usually have a noticeable increase in the capacity factor, as new plants generally employ improved technologies and enjoy maximum hydraulic flow.[189]

Figure 6.1 shows the trend in hydroelectric asset value by region from 1995 to 2020. Again, the growth of East Asia and the Pacific—largely driven by China—stands out clearly here and the significant global increase is equally apparent. The same data, normalized by population, are shown in Figure 6.2. Here the story that emerges is somewhat different. East Asia and the Pacific significantly increases hydroelectric asset wealth per capita, but it does so at a much lower level than North America and the Latin America and Caribbean region, both of which produced about three times more hydroelectric asset wealth per capita in 2020 than East Asia and the Pacific. Globally, the growth from 1995 to 2020 is much less impressive when considered in per capita terms. So, while hydroelectric asset wealth is growing overall, it is not at a rate much faster than population growth.

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[187] Capacity factor is the ratio between actual generation each year and the theoretical maximum generation if all installed capacity operated at full output throughout the year. Variables influencing the capacity factor include weather (less precipitation means less waterflow is available to keep reservoirs full); age of generating equipment (equipment tends to decline in efficiency as time goes by); regularity of repair and maintenance of equipment; unplanned outages; lower than expected demand; quality of operations; and limitations on waterflow from competing needs (for example, irrigation, fish migration) or sedimentation of reservoirs. The capacity factor in each country is weighted by the country's share of regional (global) hydroelectric power generation in calculating the regional (global) weighted average capacity factor.

[188] East Asia and the Pacific increased its generational efficacy, but only marginally.

[189] About 0.5 percent to 1 percent of the total volume of water stored in hydro reservoirs around the world is lost annually because of sedimentation. As a result, global per capita reservoir storage has rapidly decreased since its peak in about 1980. Current storage is equivalent to levels that existed nearly 60 years ago (Schellenberg et al. 2017).

TABLE 6.2

Hydroelectric asset value, installed capacity, generation, and weighted average capacity factor by region, 1995 and 2020

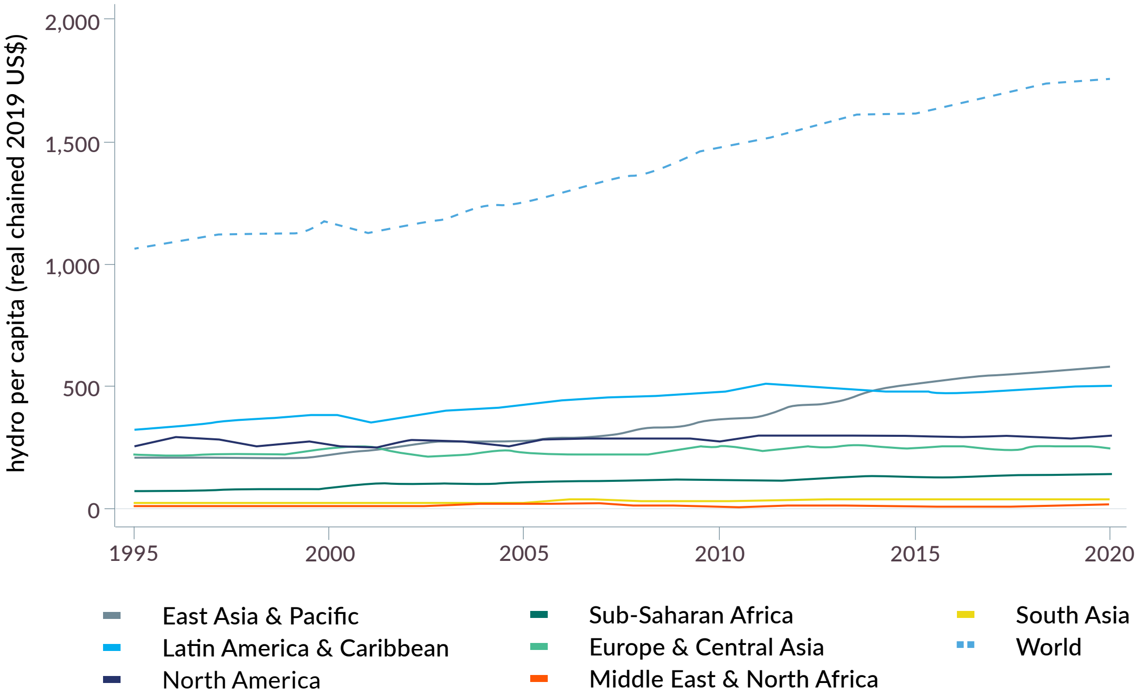
Region[1]	1995				2020			
	Hydroelectric asset value (million chained 2019 US$)	Installed capacity (MW)	Generation (GWh)	Weighted average capacity factor	Hydroelectric asset value (million chained 2019 US$)	Installed capacity (MW)	Generation (GWh)	Weighted average capacity factor
East Asia and the Pacific (4,1)	390,656	99,664	359,286	0.426	1,134,255	433,467	1,606,162	0.430
Europe and Central Asia (3, 4)	401,783	215,228	744,168	0.449	454,350	275,712	890,353	0.424
Latin America and the Caribbean (1,2)	628,449	106,566	491,777	0.543	961,673	197,485	722,329	0.435
Middle East and North Africa (7, 7)	1,216	6,498	20,512	0.427	5,382	17,685	40,817	0.363
North America (2, 3)	509,042	144,886	646,638	0.521	560,621	165,123	673,646	0.478
South Asia (6, 6)	33,799	26,808	98,887	0.429	68,474	59,343	208,846	0.405
Sub-Saharan Africa (5, 5)	103,318	15,966	46,333	0.445	249,591	27,807	118,961	0.527
World	2,068,263	615,616	2,407,602	0.483	3,434,346	1,176,622	4,261,114	0.438

Source: World Bank staff estimates.

Note: Numbers in brackets represent the global ranking of the region in terms of hydroelectric asset value in 1995 and 2020, respectively.

FIGURE 6.1

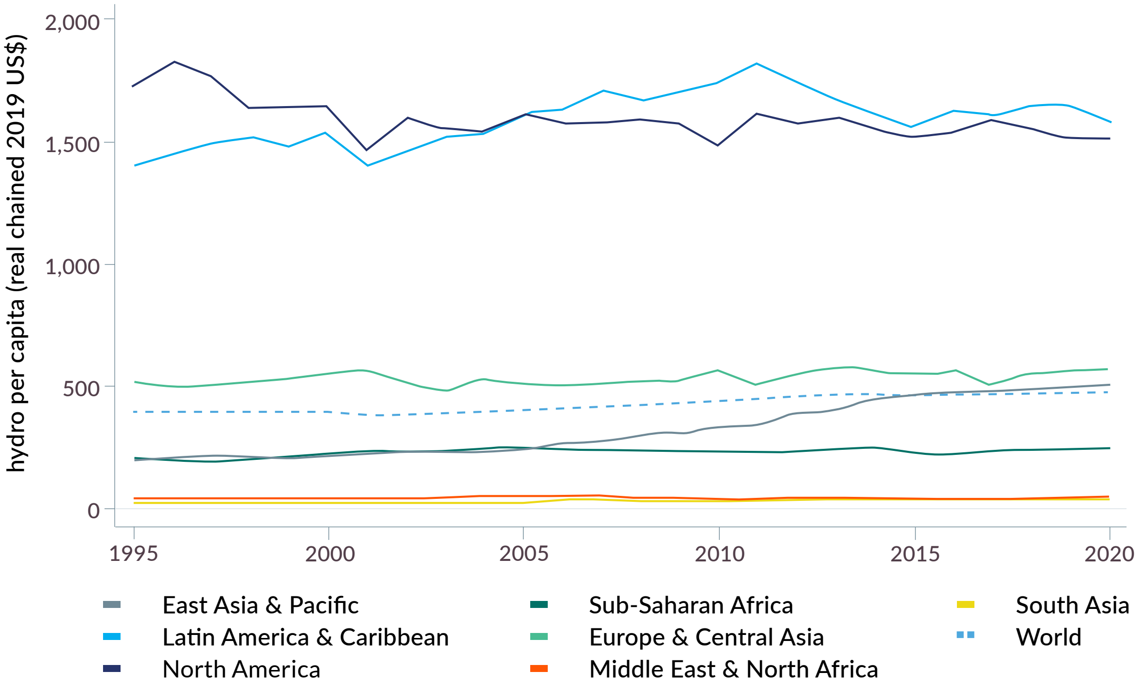
Hydroelectric asset value by region, 1995–2020



Source: World Bank staff estimates.
Note: Wealth per capita is measured in chained 2019 US dollars.

FIGURE 6.2

Hydroelectric asset value per capita by region, 1995–2020



Source: World Bank staff estimates.
Note: Wealth per capita is measured in chained 2019 US dollars.

Table 6.3 presents the same variables as in Table 6.2 but for the 10 countries with the highest hydroelectric asset values in 2020. China had the largest asset value in 2020, though it had ranked only fourth in 1995. Brazil and Canada rounded out the top three in 2020, having been bumped from first and second places in 1995, respectively, by China's emergence as the world's leading hydroelectric power producer. This move into first place in 2020 was thanks to the more than sixfold increase in Chinese generating capacity between 1995 and 2020. Only one country, Vietnam, ranked in the top 10 in 2020 but not in 1995. Vietnam rose from 28th in 1995 to sixth in 2020 due to an investment program that increased its hydroelectric generating capacity more than sevenfold over the period. One country, France, ranked in the top 10 in 1995 (in eighth place) but not in 2020 (falling to 16th place).

TABLE 6.3

Ten wealthiest hydroelectric countries, 2020

	1995				2020			
Country	**Hydroelectric asset value (million chained 2019 US$)**	**Installed capacity (MW)**	**Generation (GWh)**	**Capacity factor**	**Hydroelectric asset value (million chained 2019 US$)**	**Installed capacity (MW)**	**Generation (GWh)**	**Capacity factor**
China (4, 1)	112,061	51,135	186,622	0.417	793,606	340,504	1,321,641	0.443
Brazil (1, 2)	447,673	51,346	253,905	0.564	698,834	109,306	396,355	0.414
Canada (2, 3)	398,369	64,573	335,933	0.594	458,342	81,311	386,506	0.543
Japan (3, 4)	182,157	21,171	84,454	0.455	169,977	28,139	78,807	0.320
United States (5, 5)	110,672	80,313	310,706	0.442	102,278	83,811	287,140	0.391
Vietnam (28, 6)	9,178	2,827	10,582	0.427	63,680	20,972	73,422	0.400
Sweden (7, 7)	53,168	15,725	68,074	0.494	56,538	16,406	72,389	0.504
Italy (10, 8)	43,297	15,868	38,224	0.275	53,863	18,755	47,552	0.289
Paraguay (9, 9)	43,771	6,861	39,712	0.661	51,110	8,785	46,371	0.603
New Zealand (6, 10)	57,377	5,259	27,532	0.598	50,571	5,434	24,266	0.510

Source: World Bank.
Note: Numbers in brackets represent the global ranking of the country in terms of hydroelectric asset value in 1995 and 2020, respectively.

Table 6.4 normalizes the values from Table 6.3 by dividing them by installed hydroelectric generating capacity to enable a comparison of how successful the 10 wealthiest hydroelectric countries were in turning their resources into wealth. Normalized values better suit such a country comparison, since a megawatt of installed capacity does not differ greatly from one country to the next, but the wealth created from it can. Unit wealth created from renewable energy resources is, then, a useful measure of a country's relative success in effectively exploiting its hydroelectric asset base to generate well-being for its citizens.

Interestingly, Table 6.4 shows that of the 10 countries with the greatest hydroelectric wealth in 2020, only New Zealand made it into the top 10 countries globally in terms of wealth generation per unit of installed capacity, and only in 1995. New Zealand ranked 15th globally in this regard in 2020, creating $9.3 million (chained 2019 US dollars) per MW of installed capacity in that year. This was more than twice the global average of $4.5 million per MW in 2020. Brazil and Japan were the next most effective at turning hydroelectric resources into wealth in 2020, creating $6.4 million and $6 million per MW, respectively. Half of the other 10 wealthiest countries (Brazil, Canada, Japan, New Zealand, and Paraguay) generated more wealth per MW than the global average. The United States, at just $1.2 million per MW, was last among the 10 countries in terms of creating wealth from its hydroelectric resources, far below the global average. Had the United States generated wealth from its hydroelectric resources at just the global average rate of $4.5 million per MW, its assets would have been worth close to $400 billion in 2020, quadrupling its actual hydro wealth. China also stands out for a low rate of conversion of resources into wealth, generating only $2.3 million of value per MW of installed capacity. Notably, every country in Table 6.4 other than China and Italy saw its global ranking in wealth creation per MW slip from 1995 to 2020.

The results in Table 6.4 show that most of the 10 wealthiest hydroelectric countries have become less successful in generating wealth from their hydroelectric resources over time. In addition, they are no more successful on average than other countries in converting hydroelectric resources into wealth—several of them much less so. Clearly, having large and valuable hydroelectric assets does not mean these resources are exploited as effectively as they might be. The reasons for this trend are likely multifaceted, and assessing them was beyond the scope of this study, but it is clear that the declining efficiency of hydroelectric systems (as measured by capacity factor) played a role in the declining effectiveness of converting resources into wealth in several countries (Brazil, Japan, the United States, Vietnam, Paraguay, and New Zealand), As shown in Table 6.3, these six countries all experienced considerable declines in capacity factor from 1995 to 2020.

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190 For example, the figure in the upper righthand corner of Table 6.4 indicates that China created $2.3 million (chained 2019 US dollars) in hydroelectric asset value per unit of installed generating capacity in 2020.

TABLE 6.4

Hydroelectric asset value per unit of installed capacity, 10 wealthiest hydroelectric countries, 1995 and 2020

Country	1995	2020	CHANGE 1995–2020
	Hydroelectric asset value per unit of installed capacity (million chained 2019 US$/GWh)	Hydroelectric asset value per unit of installed capacity (million chained 2019 US$/GWh)	Percent
China (64, 63)	2.2	2.3	4.5%
Brazil (15, 24)	8.7	6.4	-26.4%
Canada (29, 28)	6.2	5.6	-9.7%
Japan (16, 25)	8.6	6.0	-30.2%
United States (74, 80)	1.4	1.2	-14.3%
Vietnam (48, 53)	3.2	3.0	-6.3%
Sweden (47, 50)	3.4	3.4	0.0%
Italy (57, 54)	2.7	2.9	7.4%
Paraguay (27, 26)	6.4	5.8	-9.4%
New Zealand (9, 15)	10.9	9.3	-14.7%

Source: World Bank.
Note: Numbers in brackets represent the global ranking of the country in terms of hydroelectric asset value in 1995 and 2020, respectively.

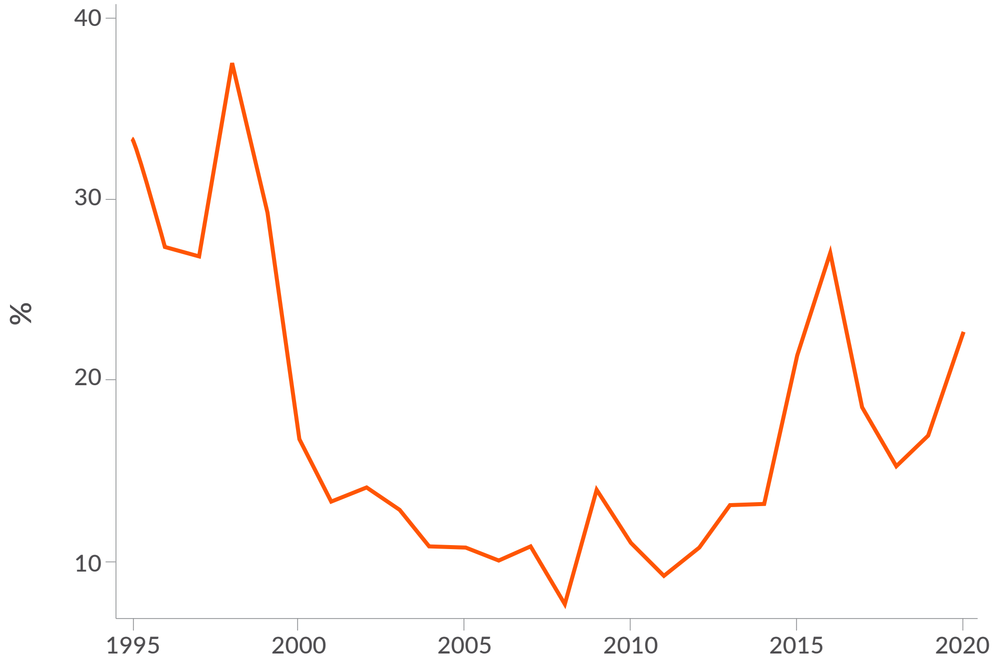
DISCUSSION OF RESULTS AND FUTURE RESEARCH AGENDA

Several lessons have emerged from this first effort to develop global hydroelectric asset values. First, there are sufficient data available from global and national sources to implement the NPV-RVM approach for the valuation of hydroelectric assets, although data on electricity prices and the costs of generation are not as robust as those on the quantities of electricity generated or the installed generating capacity. Further, and more importantly, NPV-RVM produces results that cohere with the theoretical expectation that positive resource rents arise where natural resources are exploited in competitive markets with mature technologies (Smith et al. 2021). The results of this study show that hydroelectricity resources do, indeed, generate positive rents and asset values in most countries and years.

Second, the estimated values for hydroelectric assets are globally consequential. In total, 2020 hydroelectric assets were valued at $3.6 trillion (chained 2019 US dollars). This places them at the same level as other renewable natural resource assets. Global fisheries are estimated to have been worth $21.8 trillion in 2020. The corresponding value for global timber assets is $2.8 trillion. These results show that leaving hydroelectric assets off national balance sheets misses a great deal of natural wealth. Yet, no country today includes hydroelectric assets (or any other renewable energy asset) on its national balance sheet. This omission is particularly significant for countries with large hydroelectric resources. In Paraguay, the estimate of hydroelectric asset value represents 47 percent of the country's total 2020 natural capital. In Japan, the corresponding figure is 13 percent. For these countries, the inclusion of hydroelectric assets gives an entirely different view of the contribution of renewable natural capital to overall wealth.

In China, Brazil, and Canada, the three wealthiest countries in terms of hydroelectric assets in 2020, hydroelectric assets are comparable in value to the countries' fossil fuel assets, which were valued at $1,421.2 billion, $66 billion, and $162 billion, respectively, in 2020.[191] Globally, hydroelectric assets represented 23 percent of all energy assets[192] in nominal terms in 2020. Figure 6.3 illustrates that, when calculating wealth in current nominal terms, the share of hydroelectric assets in total energy wealth is inversely correlated with global fossil fuel prices. For example, in 2020 the share of hydroelectric asset value increased because fossil fuel prices hit bottom due to the COVID-19 pandemic. Similarly, the hydroelectricity share was high in 2016 because of low fossil fuel prices in that year due to weakness in financial markets and oversupply of crude oil.

FIGURE 6.3
Share of hydroelectric asset value in total energy asset values



Source: World Bank staff estimates.
Note: The share is calculated as the nominal value of hydropower wealth divided by the sum of the nominal value of hydropower, coal, oil, and natural gas wealth. All values calculated using nominal current market (or market-imputed) US dollars.

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[191] If the contribution of fossil fuel assets to climate change were netted against their value, then hydroelectric assets (which make smaller contributions to climate change) would appear even more valuable in relative terms.

[192] Energy assets include fossil fuel, coal, natural gas, and hydroelectric assets.

It is possible that hydroelectric assets have not been included on any nation's balance sheet to date because international statistical guidance on wealth accounting (both in the SNA and the SEEA-CF) has been unclear in terms of concepts and methods for their valuation (Smith et al. 2021). This will soon change, however, as the updated SNA handbook expected to come into effect in 2025 will include guidance on valuing renewable energy assets using the NPV-RVM method adopted in this study. The details of this proposal are available in an endorsed guidance note on the UN website (Smith and Peszko 2022).

Finally, while the validity of NPV-RVM for valuing hydroelectric assets is supported by the results here, the approach could be further stress-tested using alternative valuation methods. As discussed by Smith et al. (2021), an approach known as the least-cost alternative method has been used to value hydroelectric assets in several other studies. Application of the least-cost alternative method to countries with substantial hydroelectric resources and different electricity market structures could aid in validating the results of the method presented here. In addition to further testing to validate the NPV-RVM approach, the points below could also be investigated in future.

- **Producer prices.** As discussed earlier, the approach to estimating prices received by hydroelectric producers here has important limitations. A means to improve this data would be to compile a global database of average annual wholesale electricity market prices. Such prices are likely to be close to the prices received by hydroelectric producers, at least in countries with open and competitive electricity markets. Such a database would also have shortcomings, however, as annual average electricity prices would fail to capture the dynamics of electricity markets, which can be important in countries using spot market pricing. Wholesale market prices will also not reflect the prices received by hydroelectric producers in cases where those producers have negotiated long-term power purchase agreements (PPAs) that allow them to receive steady revenue streams regardless of price trends in wholesale markets. The extent to which average annual wholesale prices accurately reflect the prices received by producers and the extent to which PPAs include subsidies could be validated by undertaking detailed studies of the hydroelectric industries in specific countries.
- **Treatment of subsidies.** Subsidies are not accounted for in the valuation of hydroelectric assets here. This was done to ensure consistency in the valuation of all natural resources across the CWON natural capital accounts. As discussed earlier, although international guidance on natural resource valuation recommends adjustment for subsidies and taxes in estimating resource rent, the practice in national statistical offices is generally to leave subsidies in due to the lack of data. Resolving this issue would require a global database of subsidies received by producers and consumers of natural resource commodities that could be used to estimate resource rent net of subsidies. Such a database would be challenging to build, but good work in that direction—at least, for subsidies to fossil fuels—is already being done by the OECD (2022), the International Institute for Sustainable Development's Global Subsidies Initiative (no date), and the IEA (2023).
- **Non-electricity income.** Some water reservoir operators are remunerated for services not related to electricity generation, for example, irrigation, water supply, recreation, and flood control. The extent to which the costs associated with these services are included in available data on costs associated with electricity production requires further investigation. In principle, only costs associated with electricity production should be included in valuing hydroelectricity assets.
- **Initial produced capital stock estimates and depreciation profiles.** The approach used to estimate the value of the initial (1994) stock of produced hydroelectric generating infrastructure could be improved. This is especially important in countries where a high percentage of installed generating capacity was already in place in 1994. A related matter is the depreciation profile applied to the produced capital stock. A very simple profile was assumed: constant

linear depreciation over a 60-year lifetime for the generating infrastructure. Several aspects of this choice merit further investigation. Is the assumed 60-year lifetime reasonable in all cases? Do hydroelectric reservoirs and dams typically last longer, for example? Should all infrastructure be assumed to depreciate linearly, or should other profiles be considered?

- **Returns to produced capital.** Due to a lack of suitable information on rates of return to produced capital by country, regional rates were assumed. This is not ideal and additional research should be undertaken to identify country-specific rates for the next edition of CWON.

- **Operation and maintenance costs.** Due to a lack of actual operation and maintenance data, such costs were assumed to be a constant share of the produced capital stock, and these shares were assumed to apply equally across countries. It would be preferable to have directly observed data on operation and maintenance costs, as they can be sizable, particularly in countries with low hydroelectricity capacity factors.

- **Valuation of solar, wind, geothermal, and other renewable energy assets.** Inclusion of renewable energy assets beyond hydroelectric assets was not possible here due to data limitations. The main hurdle preventing the inclusion of solar and wind assets was the lack of a suitable time series of producer price data for solar/wind producers. The producer prices that were estimated for hydroelectric producers were not suitable for use in valuing solar/wind assets because those prices were designed to reflect prices in wholesale markets. While such prices are an acceptable proxy for the prices received by hydroelectric producers, this is not the case for solar/wind producers where large subsidies are paid directly to producers in the form of feed-in tariffs, technology and site-specific auctions, or other commercial arrangements under the PPAs. If those prices were used to value solar/wind assets, these would have been substantially undervalued compared to other renewable natural capital assets, including hydroelectric assets. For geothermal assets, it may well be that the data required to value them are available at the national level in countries where such resources are important (such as El Salvador, Iceland, Kenya, New Zealand, and the Philippines), but carrying out valuations for individual countries using national data is not feasible for CWON, which relies on the availability of global databases to ease the burden on human and financial resources required for the compilation of comprehensive wealth accounts for 150 countries. The same could likely be said for valuing the direct use of solar heat for hot water heating, evaporation, and drying. The next step in the valuation of these assets would be a pilot study to test concepts and methods and assess available data sources, as was done for hydro, solar, and wind electricity assets in CWON 2021.

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Annex A4: Concepts of Resource Rent and Their Applicability to Hydroelectric Assets

All resource rent concepts share a focus on the benefits accruing to a factor of production over and above what is required to maintain that factor in the productive process, though they highlight different circumstances by which these payments come about. The concepts can be roughly categorized as follows (Sinner and Scherzer 2007).

- Ricardian/differential rents—rents that accrue to the more productive factors of production in homogenous input markets. In equilibrium, the price at which the least-productive firm is willing to produce clears the market; all firms with marginal costs below this price earn Ricardian (also called “differential”) rents (Hartwick and Olewiler 1999). Classical economists recognized that the location of a resource could be the source of Ricardian rents.
- Scarcity/absolute rents—rents that arise when demand exceeds supply in the long term. Since supply cannot be increased either for natural (fixed physical stock) or arbitrary (regulated entry barriers) reasons, “limits on the supply of a resource allow producers to charge prices greater than their marginal cost” (Rothman 2000, 4).
- Marshallian short-run/quasi rents—rents that arise in the short term; that is, in the absence of a stable long-term equilibrium. Quasi-rents arise when demand exceeds supply at a fixed point in time and are dissipated as the prospect of rent capture encourages more entrants to the market.

In all cases, the fundamental source of rent is scarcity. Wessel (1967) considers that Ricardian rent is essentially a pure scarcity rent, as it is the scarcity of more productive factors that allows them to earn differential rents. Such pure rents can be taxed or otherwise collected by society, as the collective resource owner, without reducing incentives to invest by energy producers. If scarcity is not permanent, Marshall’s “quasi-rents” emerge until long-term equilibrium is reached.

Not all renewable energy markets[193] can be in long-term competitive equilibrium, especially not those in the rapidly emerging areas of solar and wind energy. This has implications for the nature and level of rent and its distribution among factors of production. For example, Ricardian/differential and scarcity/absolute rents are based on the supposition of market equilibrium. By contrast, Marshallian quasi-rents are features of markets that are not in long-term equilibrium.

An additional challenge is that the inexhaustible nature of renewable energy resources poses challenges to theories of value and thus to theories of rent.[194] This is most obvious for wind and solar resources, though it applies to hydroelectric resources as well. Scarcity and differential rents arise locally, however, as a given site can only be used for solar/wind/hydro electricity production by one economic unit at a time and because the resources themselves are variable in quality (wind currents are not the same everywhere, the intensity of the sun varies with latitude, and the hydraulic characteristics of rivers differ). Scarcity may also be arbitrarily imposed; for example, through legislation granting excludable rights to generate and sell energy on these sites.

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[193] Renewable energy markets are here understood as more than just markets for electricity produced from renewable sources. They also include markets for producers of renewable energy generation technologies and their supply chains.

[194] A related measurement problem arises when the supply of resources is increasing over time (or total expenditures are growing): a declining cost share of the resource is equated with declining productivity in growth accounting, producing a biased view of the contribution to economic growth over time. Santos et al. (2016) explore this issue with regards to structural changes in the energy supply in Portugal.

7 Forests and Agricultural Lands

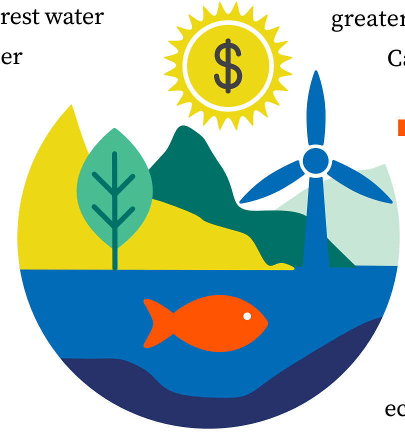
MAIN MESSAGES

- Wealth per capita in land assets declined globally between 1995 and 2020. Declines were recorded in all land asset categories: agricultural lands (24 percent decline), forest recreation services (18 percent decline), non-wood forest products (27 percent decline), forest water services (26 percent decline), and timber (28 percent decline). This means that investments in land assets have not compensated for population growth.

- The share of land assets in total wealth varies greatly across regions and income groups. In Sub-Saharan Africa and South Asia land assets represent the largest shares, about 30 percent and 32 percent in 2020, respectively. Agricultural lands and forest wealth represent less than 10 percent in other regions.

- Low- and lower-income countries show the greatest declines in wealth per capita in land assets. Timber wealth and non-timber forest ecosystem services fell by more than 50 percent in low-income countries and by more than 30 percent in lower-middle-income countries. Low-income countries as a group increased their area of agriculture by 4 percent, while losing 5 percent of forest area between 1995 and 2020. However, this has not been reflected in greater wealth per capita in land assets, partly because of high population growth rates.

- Wealth per capita in land assets experienced a decline in all asset categories for most regions. Sub-Saharan Africa shows the greatest declines, particularly in forest water services, timber, and non-wood forest products (over 50 percent decline), followed by the Middle East and North Africa, and Latin America and the Caribbean (between 30 percent and 40 percent decline in all assets). Only Europe and Central Asia show a small increase in per capita wealth in forest recreation services.



- In 2020, water protection services represented the greatest share of non-timber forest ecosystem services in all regions except in the Middle East and North Africa. The share of water protection services was greater than 70 percent in Latin America and the Caribbean, North America, and South Asia.

- A key innovation of this edition of CWON is that it provides a first global estimate of the value of protected areas based on the non-timber forest ecosystem services they provide. Their contribution is significant, providing 16 percent of the total wealth provided by forest non-timber ecosystem services. Their contributions vary considerably by world regions, with the highest percentage of wealth provided by protected areas in Sub-Saharan Africa (21 percent).

INTRODUCTION

Forests and agricultural lands play a fundamental role in fostering economic development. They offer a range of benefits, from livelihood opportunities to essential ecosystem services that contribute to economic growth and sustainability (World Bank 2021b; FAO 2022; Dasgupta 2021).

Forests are not merely a source of timber or wood products. They provide crucial ecosystem services, such as regulating water cycles, preventing soil erosion, maintaining biodiversity, and opportunities for recreation that support vibrant tourism industries in many countries (IPBES 2019). Their role in climate regulation is increasingly recognized as a key asset in the fight against climate change, further contributing to the economic well-being of societies (IPCC 2019, 2023).

Agricultural lands are the foundation of food production and essential economic development in low- and middle-income countries. They not only provide a vital source of sustenance but also underpin global trade and agribusiness

(Zabel et al. 2019). In addition, the agricultural sector offers employment to a substantial portion of the global population (FAO 2023), particularly in developing countries, contributing significantly to their economies.

Although not studied in this chapter, the synergy between forests and agricultural lands is also critical. Forests support agricultural productivity by regulating ecosystem services and habitat for pollinators and natural pest control (Johnson et al. 2021). In turn, agriculture can positively influence forests by promoting agroforestry systems, which combine the cultivation of trees with agricultural crops, enhancing land productivity while preserving forest cover (Miller et al. 2020). The delicate balance between these land assets is vital for sustainable economic development. Recognizing the importance of conserving and sustainably managing both forests and agricultural lands is crucial to maintaining their economic contributions while safeguarding the planet's long-term health.

This chapter first describes the main data sources and methods used to estimate the value of agricultural land and forests. Next, it presents the main trends in agricultural land (cropland and pastureland) and forests (timber and non-wood forest ecosystem services) from 1995 to 2020, which are disaggregated by region and income group. Additionally, for the first time, this edition of CWON estimates the value of forest ecosystem services provided by protected areas.

MEASURING LAND ASSETS

Agricultural land

Agricultural land constitutes a considerable portion of total wealth in developing countries, particularly in the low-income group. For this report's purposes, agricultural land includes cropland and pastureland. There are potentially two different methods for estimating land wealth. The first method uses information from the sale of land. The second method uses information on the annual flow of rents that the land generates 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.

For each country in the database, *annual resource rents* in agricultural lands TR_t are the sum of the rents $R_{k,t}$, for each crop/livestock product k, in year t. Rents are the product of price $p_{k,t}$, quantity produced $q_{k,t}$, and the average rental rate parameter a_t:

$$1) \qquad TR_t = \sum_{k=1}^{n} R_{k,t}$$

where:

$$2) \qquad R_{k,t} = \left(p_{k,t} \times q_{k,t} \times a_t\right)$$

and $k = 1,\ldots,n$ for the number of crops/livestock products covered by FAO, $t = 1995$ to 2020 , or the latest year available, and a_t is defined by the United States' International Agricultural Productivity database.[195] The rental rate is proxied by land cost shares provided by the International Agricultural Productivity database for each country and each decade. For countries where rental rates vary across decades, annual values are assumed to be constant within each decade. Because rental rates are not disaggregated for each crop/livestock product, k, FAO's gross value of production generated in cropland and pastureland is used.

The value of agricultural land is then calculated as the discounted total rents, TR_t, where r is the social discount rate (assumed to be equal to 4 percent).

$$3) \qquad V_\tau = \sum_{t=\tau}^{\tau+100} \frac{TR_t}{(1+r)^t}$$

In this edition of CWON, the estimates of wealth in agricultural lands do not consider projections of land degradation or climate change on land productivity, as was done in World Bank (2021a). Instead, future rents are assumed to be constant at 2020 values. This assumption is consistently applied across all assets.

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[195] https://www.ers.usda.gov/data-products/international-agricultural-productivity/.

FORESTS

The value of forests is estimated for two asset categories: timber resources and non-timber forest ecosystem services. Timber resources are valued according to the present discounted value of rents from the production of roundwood over the expected lifetime of standing timber resources. This value, V_t, is given by the following equation:

$$4) \qquad V_t = \sum_{i=t}^{t+T-1} \frac{R_t}{(1+r)^{i-t}}$$

where R_t is the rent for year t; r is the social discount rate (assumed to be equal to 4 percent), and T is the lifetime of timber resources capped at 100 years. Unlike metals and minerals, timber is a renewable resource, so T depends on the rate of timber extraction relative to natural rates of forest growth and resource replacement. Rents from timber in year t are calculated as:

$$5) \qquad R_t = \pi_t Q_t$$

where π_t denotes unit rents, equal to revenues less production costs, and Q_t denotes the quantity of roundwood extracted. Data on annual roundwood production are obtained from FAO's FAOSTAT database. The area of timber forest is estimated by subtracting forests located within protected areas from the total forest area, excluding protected area categories that could be used for sustainable timber production (that is, protected areas in International Union for Conservation of Nature (IUCN) categories V and VI) based on FAO's Forest Resource Assessment 2020.

The value of non-timber forest ecosystem services is based on the work of Siikamäki et al. (2024), who developed a meta-analytic predictive model using regression and machine learning techniques to spatially estimate the value of the following three ecosystem services: (i) recreation, hunting, and fishing (referred to as "recreational"), (ii) non-wood forest products, and (iii) watershed protection (referred to as "water services"). The 2024 study, which builds on the analysis conducted for CWON 2021, updates the database of non-timber forest ecosystem services values, provides a time series of ecosystem services values from 1995 to 2020, and develops a method to estimate the contribution of protected areas to the production of non-timber forest ecosystem services. This is an important departure from the lower-bound approach used in CWON 2021 and earlier reports to estimate wealth in protected areas, which relied on opportunity cost values.

Key datasets used to estimate non-timber forest ecosystem services are data on total forest area from FAO's Forest Resources Assessment 2020, annual service values per hectare of forest—estimated by Siikamäki et al. (2024) as the sum of recreational, non-wood forest products, and water services—and protected area boundaries from the World Database on Protected Areas developed by the UN Environment Programme (UNEP), World Conservation Monitoring Center, and IUCN. Siikamäki et al. (2024) analyzed hundreds of studies of non-wood forest benefits to develop a spatially explicit meta-regression model that predicts service values for 10km x 10km plots of forest around the globe.

The annual value of non-timber forest ecosystem services is estimated by multiplying total forest area by the sum of the per hectare monetary values for the three benefit categories. The capitalized value of ecosystem services is equal to the present value of annual services. The present value of non-timber services is given by the following equation:

$$6) \qquad PV(S) = \sum_{i=1}^{i=100} \frac{S \cdot F}{(1+r)^i}$$

where S is the sum of per hectare service values for the three benefit categories, F is the total forest area, and r is the social discount rate of 4 percent. No distinction is made between natural and planted forest. Values are estimated for the current forest area, assuming no change in forest cover in the future.

The value of forest carbon retention services is not estimated for this edition of CWON 2024 due to data and conceptual challenges outlined in Box 7.2, and thus not included as part of the wealth accounts.

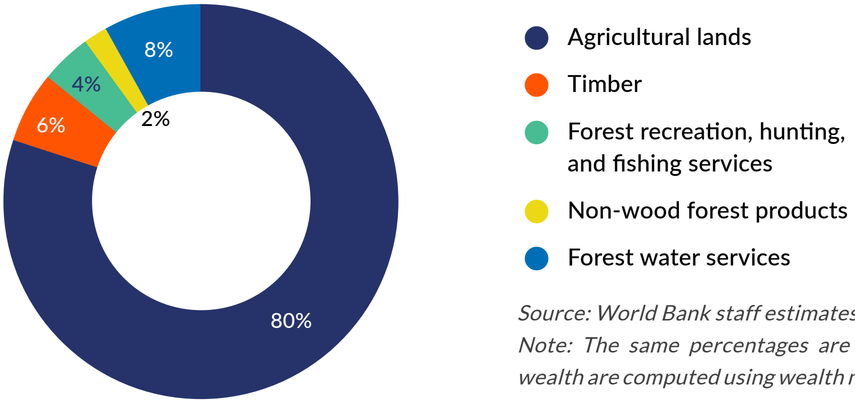
LAND ASSETS: GLOBAL AND REGIONAL TRENDS, 1995–2020

Global trends

Land assets (agricultural lands and forests) globally represent a relatively small share of total wealth, between 4 percent and 5 percent for 1995–2020, but this share varies significantly across regions and income groups. In Sub-Saharan Africa and South Asia land assets represent the largest shares, about 30 percent and 32 percent in 2020, respectively. Agricultural lands and forest wealth represent less than 10 percent in other regions. The largest category of land assets is agricultural lands, which represented 80 percent of land wealth globally in 2020, followed by forest water services (8 percent); timber (6 percent); forest recreation, hunting, and fishing services (4 percent); and non-wood forest services (2 percent) (Figure 7.1). At the global level, total wealth in land assets in per capita terms decreased across all categories: agricultural lands (24 percent decline), forest recreation services (18 percent decline), non-wood forest products (27 percent decline), forest water services (26 percent decline), and timber (28 percent decline). Any growth observed in total values of land assets did not keep up with population growth (Figure 7.2).

FIGURE 7.1

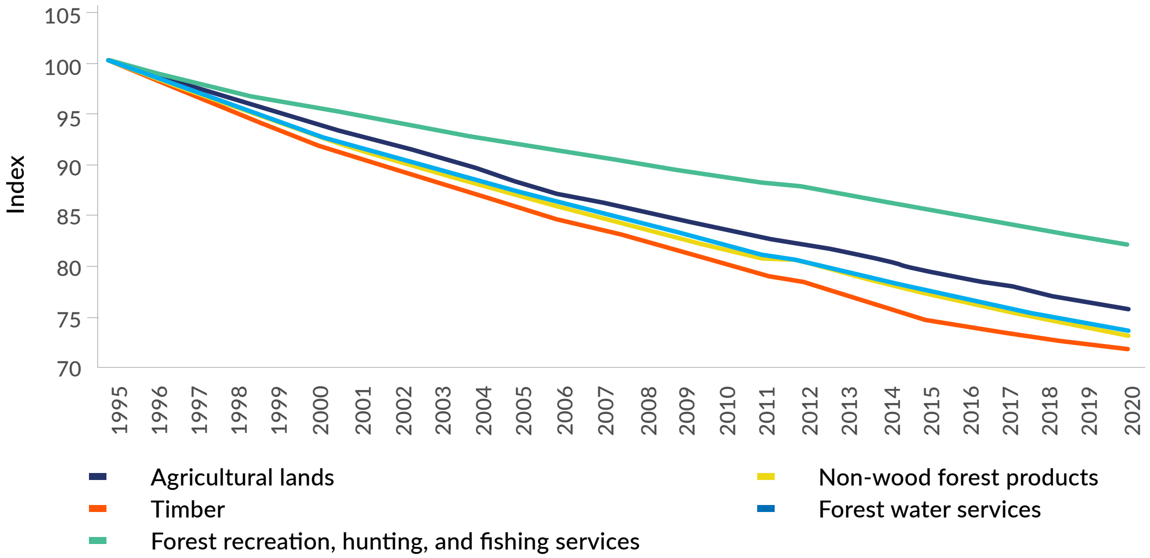
Global wealth in land assets: percent shares by category in 2020



Source: World Bank staff estimates.
Note: The same percentages are observed in 1995. Shares in wealth are computed using wealth measured in current US dollars.

FIGURE 7.2

Trends in real wealth per capita in land assets, indexed to 1995, 1995–2020



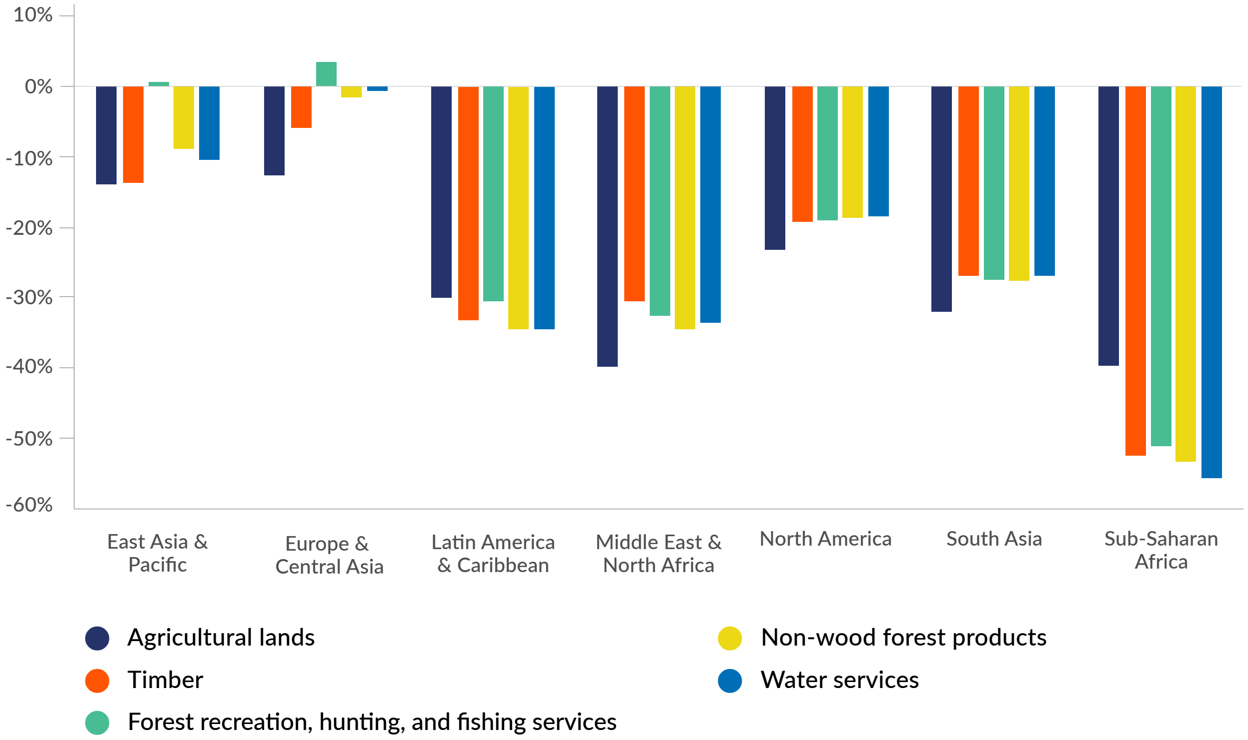
Source: World Bank staff estimates.
Note: Wealth per capita is measured in chained 2019 US dollars.

REGIONAL TRENDS

Wealth per capita in land assets experienced a decline in all asset categories for most regions. Sub-Saharan Africa shows the greatest declines, particularly in forest water services, timber, and non-wood forest products (over 50 percent decline), followed by the Middle East and North Africa and Latin America and the Caribbean (between 30 percent and 40 percent decline in all assets). Only Europe and Central Asia show a small increase in per capita wealth in forest recreation services (Figure 7.3).

FIGURE 7.3

Change in wealth per capita by land asset, 1995–2020

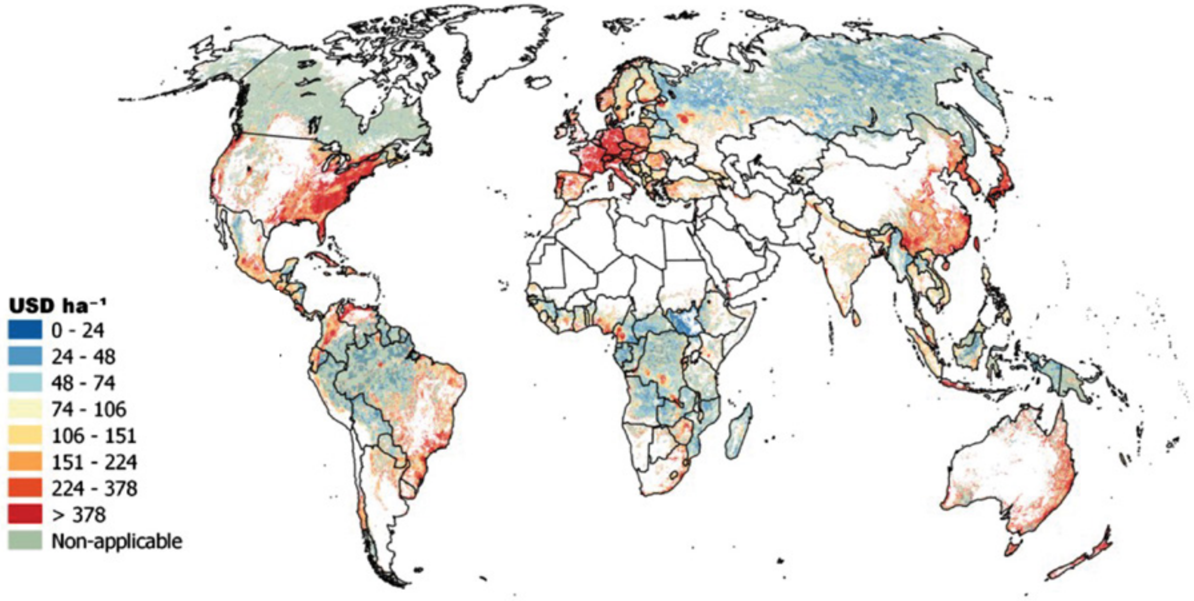


Source: World Bank staff estimates.
Note: Wealth per capita is measured in chained 2019 US dollars.

Figure 7.4 shows the combined average per hectare value in 2020 of forest ecosystem services for recreational services (including hunting and fishing), non-wood forest products, and water services. The value is mapped globally in 0.1° by 0.1° resolution for forested grid cells based on the approach implemented in Siikamäki et al. (2024). North America, Europe, and countries such as Japan and Australia feature particularly high value estimates. On the other hand, several low- and middle-income countries also show high values, including parts of Latin America and the Caribbean, and several areas in Asia, such as the densely populated areas in Indonesia and China. Africa, in general, has relatively low predicted values, but some areas in countries like South Africa, Côte d'Ivoire, Ghana, and Nigeria show relatively high values.

FIGURE 7.4

Combined predicted value of all recreational services, non-wood forest products, and water services, per hectare in 2020 (2020 US dollars)

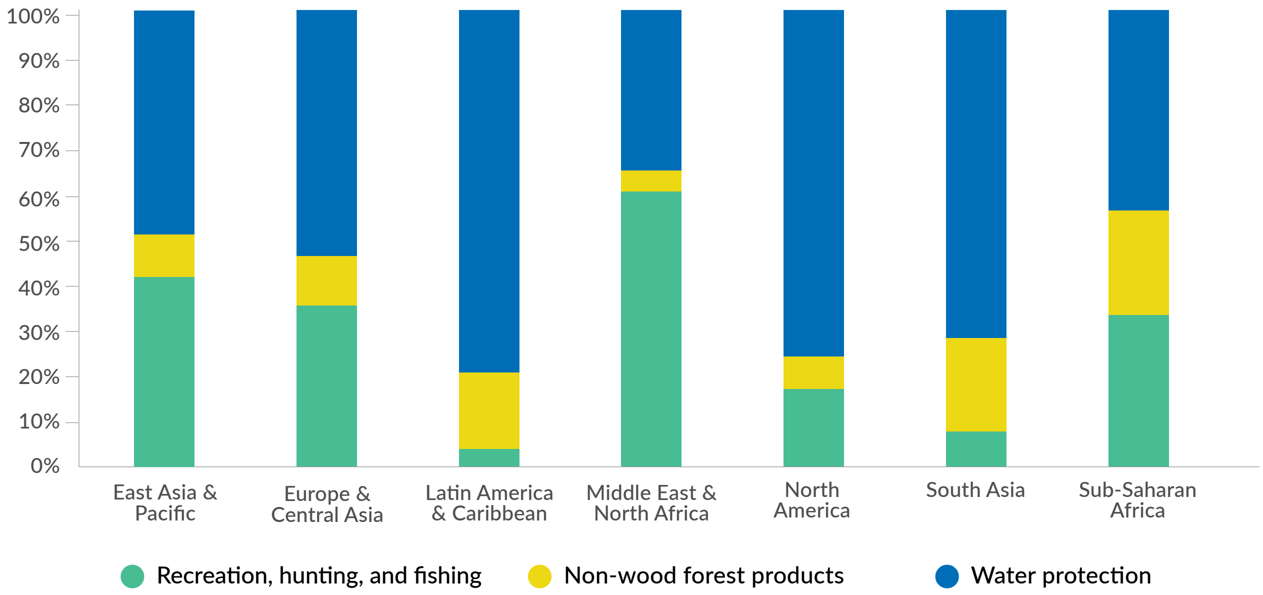


Source: Siikamäki et al. 2024.
Note: The services considered include recreational services (including hunting and fishing), non-wood forest products, and water services. For illustration purposes, only grid cells with forest cover larger than 10 percent are shown.

In 2020, water protection services represented the greatest share of non-timber forest ecosystem services in all regions except the Middle East and North Africa. The share of water protection services is greater than 70 percent in Latin America and the Caribbean, North America, and South Asia (Figure 7.5).

FIGURE 7.5

Share of forest ecosystem services by region and asset category, 2020

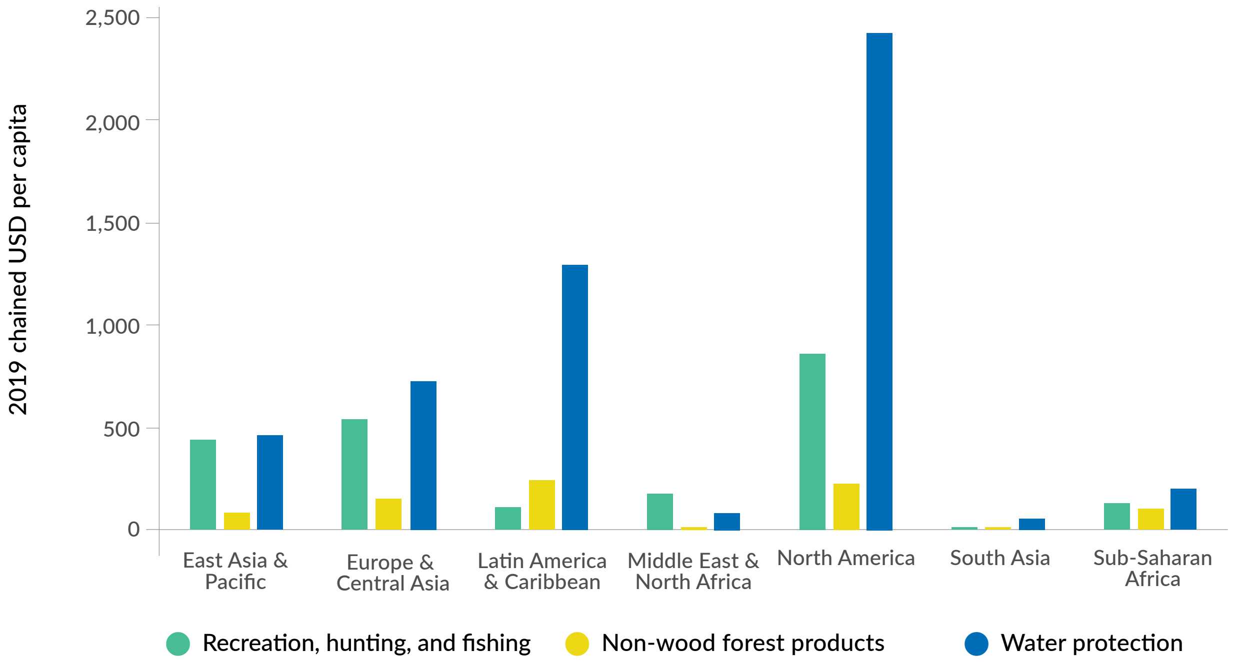


Source: World Bank staff estimates.

Per capita values of non-timber forest ecosystem services vary greatly across regions and services (Figure 7.6). Water services show the highest value per capita in all regions, except the Middle East and North Africa. North America and Latin America and the Caribbean show the highest per capita values for water services relative to other regions. Sub-Saharan Africa, South Asia, and the Middle East and North Africa show relatively low per capita values for the three non-timber forest ecosystem services, due to low-to-medium per hectare values, as well as large populations, particularly in South Asia.

FIGURE 7.6

Wealth per capita in non-timber forest ecosystem services, by region and by category of service, 2020



Source: World Bank staff estimates.
Note: Wealth per capita is measured in chained 2019 US dollars.

Protected areas cover around 15 percent of the world's terrestrial land and some 7 percent of the ocean (UNEP-WCMC and IUCN 2022).[196] Their coverage has steadily increased over time, and their current global extent nearly matches Aichi Biodiversity Target 11 of 17 percent of terrestrial and 10 percent of coastal and marine areas protected by 2020. As such, protected areas constitute a key policy instrument to ensure the conservation of nature to support biodiversity and the provision of ecosystem services to people.

Although various ecological and ecosystem contributions of protected areas are widely recognized (King et al. 2023), information on the economic value of ecosystem services provided by protected areas is not comprehensively available. Siikamäki et al. (2024) predicted the contribution of protected areas for non-wood forest products, water services, and recreation, hunting, and fishing. These results are the first available estimates of the economic value of these ecosystem service categories supported by protected areas, generated by country.

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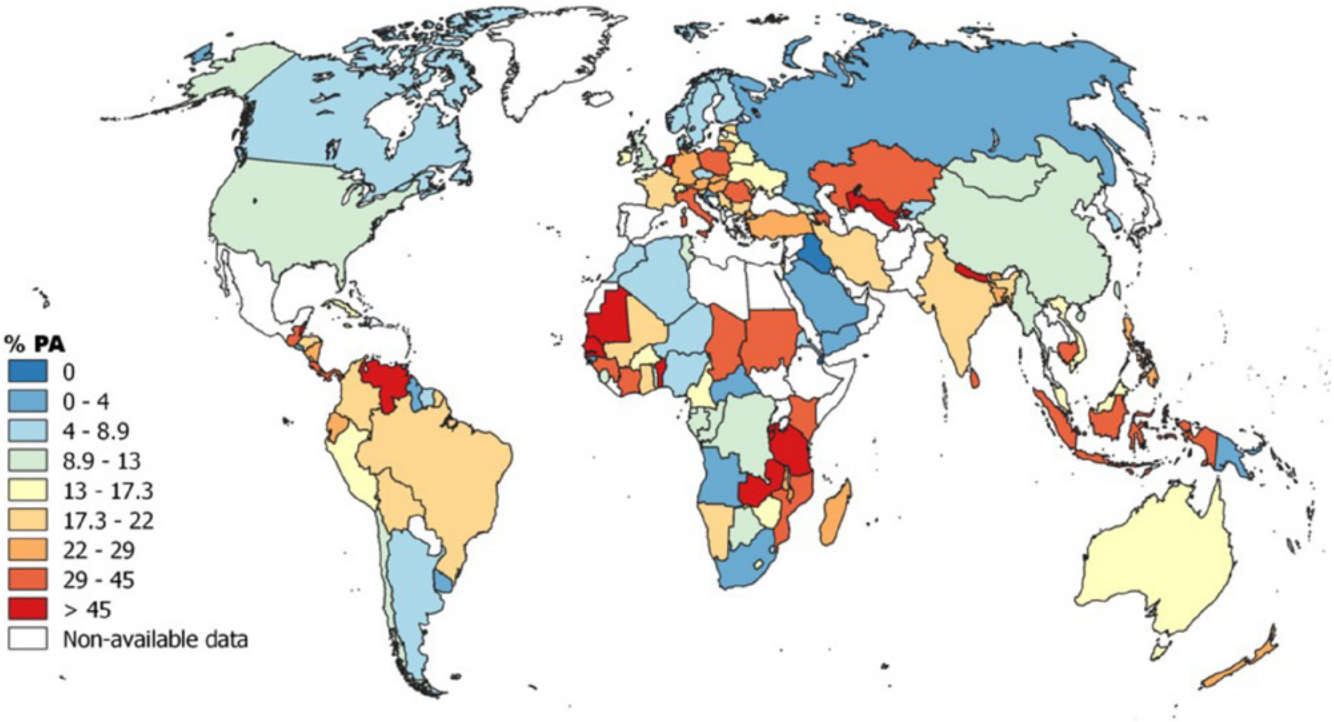
[196] Based on Wolf et al. (2021), 15.7 percent of forests are formally protected.

FIGURE 7.7

Share of national forest wealth in non-timber forest ecosystem services provided by protected areas and country, 2020



Source: Figure 6.1 in Siikamäki et al. 2024.
Note: The following non-timber forest ecosystem services are included in the estimation: recreation, hunting, and fishing; non-wood forest products; and water services.

Figure 7.7 shows the percentage of the total national wealth of forest non-timber ecosystem services provided by protected area forests, by country. The contribution of protected areas to total value is highest in several African countries, Venezuela, Nepal, Uzbekistan, and many countries in Central Europe. This is a combination of the large share of forest being protected in those countries and the value of non-timber ecosystem services in the protected areas relative to non-protected areas.

Protected areas provide 16 percent of the total wealth contributed by forest non-wood ecosystem services. The share of national forest non-wood wealth provided by protected areas varies considerably by world region, with the highest percentage of wealth provided by protected areas in Sub-Saharan Africa (22 percent), Latin America and the Caribbean (22 percent), and South Asia (22 percent), and the lowest percentage of wealth provided by protected areas occurring in the Middle East and North Africa (9 percent), Europe and Central Asia (11 percent), and North America (11 percent).

BOX 7.1

TRENDS IN LAND ASSETS: COUNTRY EXAMPLES

Taking a closer look at trends in land assets for selected countries helps us understand the underlying drivers of change in wealth per capita. Here the cases of Brazil and Ethiopia, large economies with significant land assets and populations, are presented.

Brazil has the largest forest area in Latin America and the Caribbean. It covers a large fraction of the Amazon biome, a critical natural asset for the provision of global ecosystem services and biodiversity protection (Brouwer et al. 2022). Between 1995 and 2020, the country's real wealth in agricultural lands increased by 4 percent, while its real wealth in non-timber forest ecosystem services declined by 13 percent. Over the same period, the area covered by these two asset categories followed a similar trend. Yet the country's population increased by 30 percent over the same period, leading to a decline in wealth per capita in agricultural lands of 20 percent and non-timber forest ecosystem services of 33 percent. Overall, the country shows an increase in real per capita wealth of 73 percent once all assets (produced capital, human capital, renewable natural capital, and nonrenewable natural capital) are accounted for, which is a minimum requirement for sustainable growth (under weak sustainability). Further exploration of the limited substitutability of renewable natural capital and its implications for future wealth is needed, considering the risks of reaching critical tipping points in ecosystem functions (Flores et al. 2024).

Ethiopia, the second most populous country in Africa, has an economy largely dependent on agriculture and land assets (He and Chen 2022). The country's long history of forest and land degradation represents a significant drag on rural growth and poverty reduction (UNEP 2016). Between 1995 and 2020, the country's total real wealth in agricultural lands increased by 26 percent, while real wealth in non-timber forest ecosystem services declined by 10 percent, underpinned by a loss in forest cover of a similar magnitude. But because the population doubled over the same period, per capita real wealth in agricultural lands and non-timber forest ecosystem services declined by 38 percent and 56 percent, respectively. Investments in assets other than those in the land sector barely compensated for this rapid population growth, as real per capita wealth considering all assets increased by 5 percent between 1995 and 2020. For a country where land assets represented close to 30 percent of total wealth in 2020, declines in critical sectors like agriculture and the services provided by forests indicate that much greater investments are needed in natural capital and the subset of land assets.

TRENDS BY INCOME GROUPS

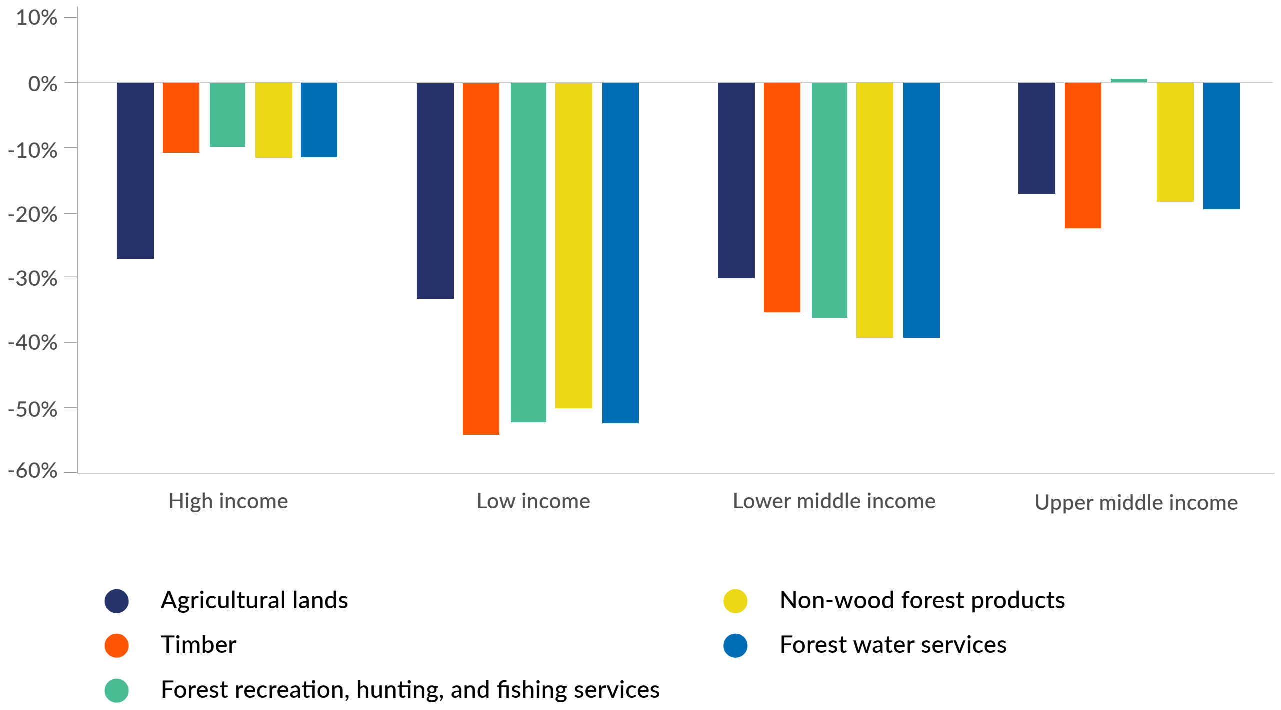
Although all income groups experienced declines in per capita wealth across land asset categories, this was a particular issue in low-income and lower-middle-income countries. Timber wealth and non-timber forest ecosystem services fell by more than 50 percent in low-income countries and by more than 30 percent in lower-middle-income countries (Figure 7.8). High-income countries show a decline in per capita agricultural wealth of 27 percent, greater than the declines observed in the forest categories.

In 2020 land assets made up 41 percent of total wealth in low-income countries, down from 78 percent in 1995. The share of land assets in total wealth fell in most low-income countries between 1995 and 2020, with a few exceptions like Niger, Guinea-Bissau, and the Central African Republic, which show the opposite trend (Figure 7.9).

In low-income countries as a group, agricultural area increased by 4 percent, while the area of forests decreased by 5 percent (Table 7.1). Yet, as the trends of wealth per capita in land assets demonstrate, this has not increased overall wealth per capita in the land sector. Countries in this group appear to be trading off forests for land in agriculture. However, this cannot be tested directly using the CWON data; this observation requires additional analysis of remote-sensing data.

FIGURE 7.8

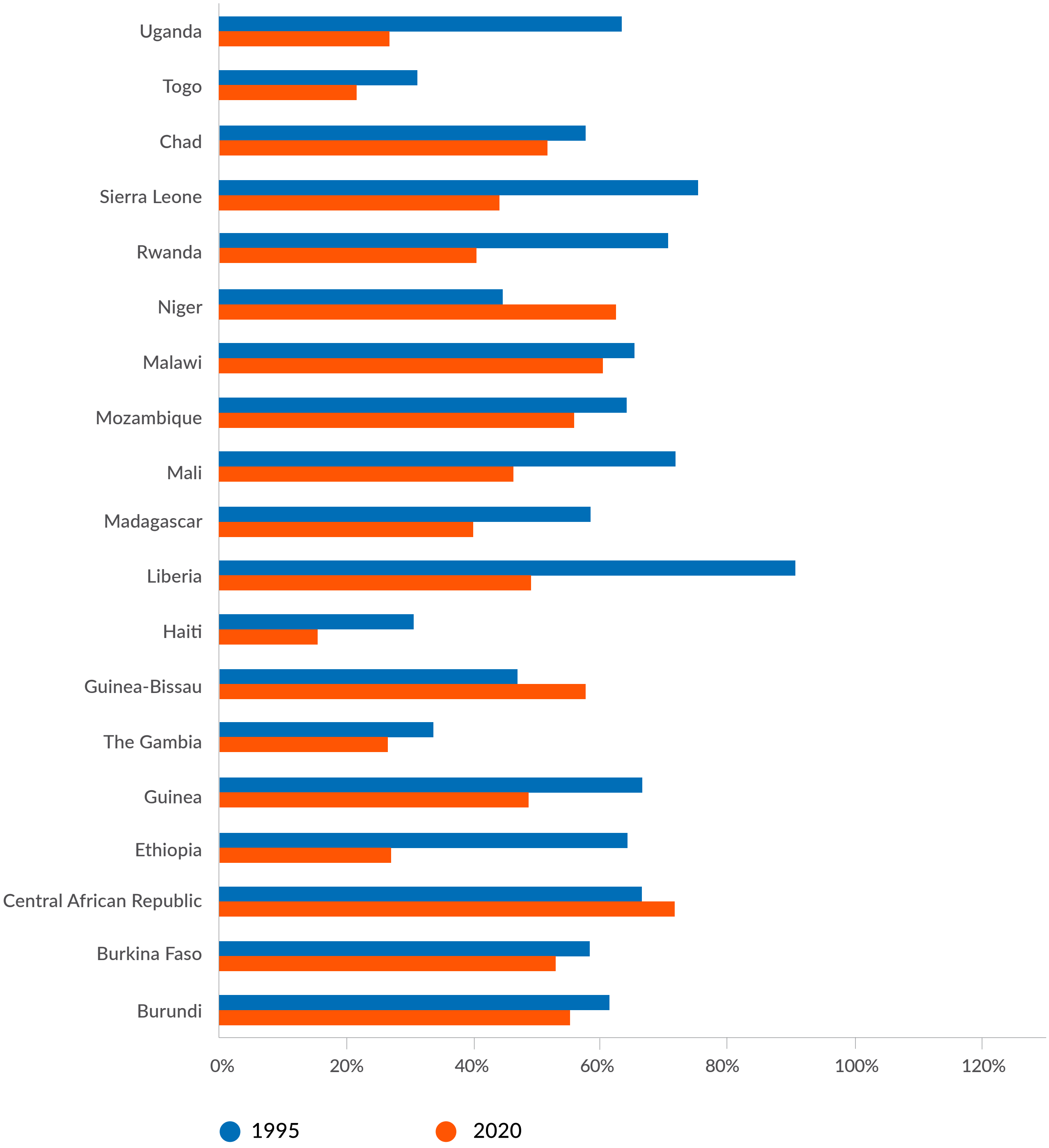
Change in wealth per capita in land assets by income group, 1995–2020



Source: World Bank staff estimates.
Note: Wealth per capita is measured in chained 2019 US dollars.

FIGURE 7.9

Share of land wealth in total wealth in low-income countries, 1995 and 2020



Source: World Bank staff estimates.
Note: Shares in wealth are computed using wealth measured in current US dollars.

TABLE 7.1

Land cover for forest and agricultural lands in low-income countries, 1995 and 2020

	AGRICULTURAL LAND (SQ KM)			FOREST LAND (SQ KM)		
	1995	2020	% change	1995	2020	% change
East Asia and the Pacific	26,500	25,900	-2%	66,834	60,301	-10%
Europe and Central Asia	45,820	49,160	7%	4,090	4,238	4%
Latin America and the Caribbean	15,900	18,400	16%	3,818	3,473	-9%
Middle East and North Africa	375,250	373,730	0%	9,511	10,711	13%
South Asia	377,530	383,560	2%	12,084	12,084	0%
Sub-Saharan Africa	4,870,350	5,085,426	4%	3,124,240	2,970,657	-5%
Total low-income countries	5,711,350	5,936,176	4%	3,220,576	3,061,464	-5%

Source: World Bank staff estimates based on data from FAO for agricultural land and forest land and data from the World Development Indicators for protected areas.
Note: sq km = square kilometers.

CONCLUSIONS

Although total global wealth in land assets (the sum of agricultural lands, timber, and non-wood forest ecosystem services) has increased slightly, wealth per capita in land has declined across all regions and for almost all assets. This trend is particularly pronounced in low-income countries as a group and countries in Sub-Saharan Africa.

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, most countries, particularly the low-income group, appear to be managing their land assets unsustainably. Greater investments and stronger policy signals are urgently needed to protect and restore forests and reverse long-term trends of nature loss and degradation. Low- and middle-income countries have large amounts of restorable land based on cost-effectiveness criteria, but the low-income group requires stronger forest governance and land tenure security to attract greater public and private investments in this sector (World Bank 2024).

This chapter does not discuss the interconnections between land assets. Further exploration is required to understand the degree to which countries and regions are trading off forest lands for agricultural lands, and the implications for changes in total wealth per capita. One way to address this is to move to fully spatially integrated land accounts in the next CWON edition. More research is also needed to assess carbon retention services as a critical climate regulation service provided by forests, as explained in Box 7.2, and to consider additional data collection and improvements to the valuation methodology for agricultural lands and timber to further improve the rent estimation.

BOX 7.2

KEY CHALLENGES IN ACCOUNTING FOR CARBON RETENTION SERVICES IN CWON

The global climate crisis is one of the most pressing sustainability challenges of our time, exacerbating existing social, environmental, and economic issues (IPCC 2022). Terrestrial ecosystems, most notably forests, can play an important role in mitigation efforts (for example, Grassi et al. 2017; Griscom et al. 2017), as they are able to both emit and absorb greenhouse gases, acting as significant stores of carbon as well as carbon sinks (for example, Cook-Patton et al. 2020; Jones et al. 2013). For these reasons, it is important to evaluate to what extent the value of climate regulation services could be included in CWON. The current wealth estimates already include several ecosystem services provided by forests (as presented in this chapter) and mangroves (see chapter 8). Adding climate regulation services would thus be a natural extension of the asset boundary.

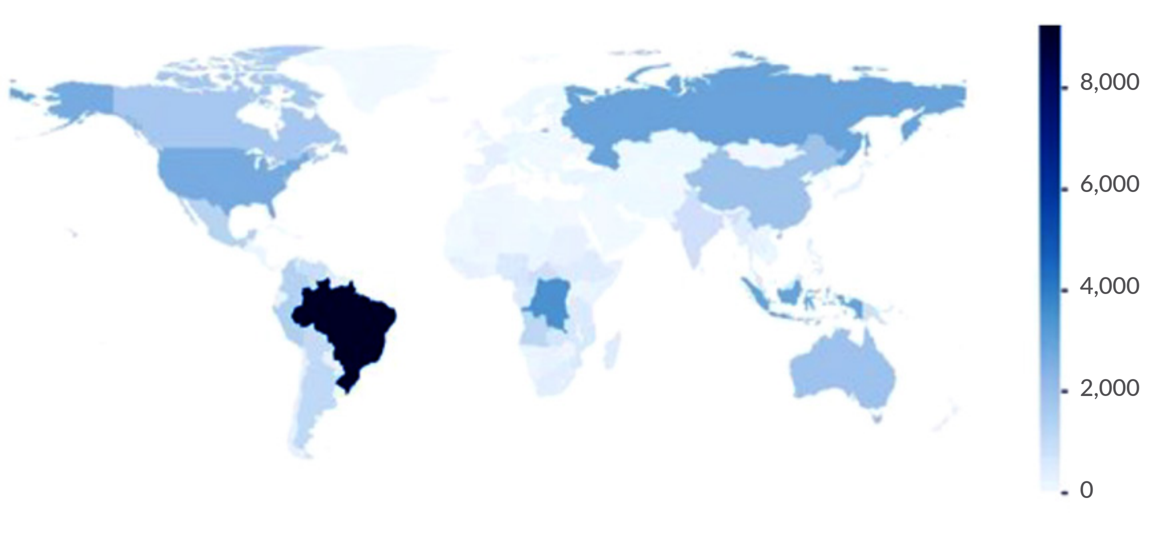
There is emerging guidance from the System of Environmental-Economic Accounting Ecosystem Accounting (SEEA-EA) on how to measure global climate regulation from terrestrial ecosystems, which can help guide how such a service could be included in CWON (Edens and Caparrós 2023). The current consensus is to measure a single service, consisting of two components: carbon sequestration, which measures the net uptake of carbon by a given ecosystem asset, such as a forest or wetland, and carbon retention, which measures the avoided release of carbon—or put differently, the ability of the ecosystem to retain carbon and thus avoid climate damages. Users are advised to choose the measurement most suitable for their context (NCAVES and MAIA 2022).

For a global assessment like CWON, carbon retention is the primary component of climate regulation services, as carbon stocks in forests and wetlands are typically not increasing for most countries (Bulckaen et al. 2024). If a country's forests are instead experiencing a clear expansion in their carbon stock, carbon sequestration should ideally be reported as an "of which" item. Unfortunately, this is currently not feasible on the global scale (Pugh et al. 2020). Any changes in carbon retention services thus capture changes in carbon stored due to anthropogenic and other factors, as well as sequestration. In addition, carbon retention is the more policy relevant measure, as a loss in carbon due to, for example, deforestation would lower carbon retention services. Similarly, ecosystems with high carbon stocks, such as tropical rainforests, would be assigned higher retention values, signaling the importance of conserving. This is not necessarily the case for carbon sequestration, which only captures changes in the carbon stock, not its level. This can lead to perverse incentives in natural resource management, where carbon sequestration would increase if a rainforest were replaced by, for example, fast-growing bamboo.

Measuring carbon retention in biophysical terms is possible by estimating vegetation carbon stocks annually using the standard methodology developed by Gibbs and Ruesch (2008) and 2006 IPCC default factors (Bulckaen et al. 2024). To estimate vegetation carbon stocks, it is assumed that each terrestrial land cover class, with a few exceptions like water bodies, glaciers, and bare rock or soil, contributes to storing carbon to varying extents. The classes with the highest contribution to carbon stock are forests and wetlands, particularly mangroves, with each contributing proportionally to the total carbon stock of a given area. These estimates can then provide annual snapshots of the stock of carbon for each year, which will change due to land cover changes (and potentially land cover reclassification) as well as the occurrence of fire and anthropogenic factors.

Estimates show that the countries with the highest share in the global value of forest carbon are tropical or large countries, such as Brazil, the Democratic Republic of Congo, Russia, Indonesia, the United States, and Canada (Box Figure 7.2.1). Brazil, being both vast and tropical, accounts for the largest share in the total forest carbon value with 18 percent. The other large tropical countries—the Democratic Republic of Congo and Indonesia—make up around 7 percent and 6 percent, respectively. Combined with the three large land area countries—Russia, the United States, and Canada—these six countries make up nearly half of the global value of climate regulation services provided by forests, underscoring the importance of sustainable forest management in these countries.

BOX FIGURE 7.2.1
Total global vegetation carbon stock (in megatons), 2020



Source: Bulckaen et al. 2024.
Note: All the code to obtain the results is available at https://github.com/integratedmodelling/im.nca.postprocessing/tree/main/aggregation_region.

The primary compilation challenge for measuring carbon retention services is to choose a suitable carbon price for the valuation of avoided climate damages. The SEEA-EA does not provide specific guidance (UN et al. 2021, paragraph 9.32), but Edens et al. (2019) and the NCAVES and MAIA (2022) discuss the suitability of using different carbon prices, such as observed market prices, the marginal abatement costs of carbon, or the social cost of carbon (SCC) in the context of national accounting. As the carbon retention framing is based on the idea of avoided damages, the recommendation is to apply a SCC estimate. While market prices would be preferable as they align with the exchange value principle of the SEEA-EA, existing carbon markets are incomplete, making them unsuitable for a global assessment. Marginal abatement cost curves exist at the global scale, but measurement concerns over underestimating costs and double counting limit their use in national accounting.

An additional complication in the context of CWON is that the wealth estimates include a range of assets, such as produced capital, agricultural land, and human capital, whose current value is directly supported by the carbon retention services provided by forests and mangroves. That is, their asset values at least to some extent capture the fact that the climate is currently stable, and that productivity is not lost due to climate damages. Adding the avoided climate damages provided by carbon retention services would result in double counting if the SCC estimate captured market benefits (to produced capital, agricultural land, and human capital, among others). To avoid potential double counting, a tailor-made SCC was estimated by Drupp and Hänsel (2023), which only captures the avoided monetized climate damages for the non-market sectors of the global economy. Based on these estimates, the global value of carbon retention services has declined by 1 percent over the last two decades. This change was driven by a dramatic loss in global forest cover equivalent to nearly 36 million hectares, an area the size of Japan or Norway.

However, several conceptual challenges around the valuation of carbon retention services still need to be resolved. First, more work is needed to inform the choice of carbon price to be used in the valuation. Second, additional theoretical and empirical research is required to assess the risk of double counting when including climate regulation (as well as other regulating services) in wealth accounts. While there is evidence that climate regulation services are partially captured in the valuation of other assets, more analysis is needed to systematically estimate this share and develop an approach to reattribute this value to ecosystem assets. Third, at this point, it is not feasible to derive country-specific estimates of the value of carbon retention services. To produce country-specific non-market SCC estimates, more refined data is required on the breakdown and distribution of climate damages into market and non-market damages at the country level, which also distinguish between use and non-use value components. It will also be critical to assess which part of the market SCC should capture to further lower the risk of double counting.

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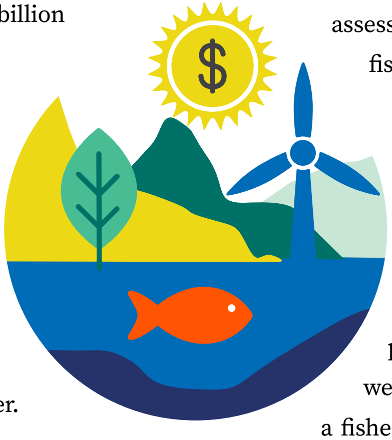
8 Blue Natural Capital: Marine Fish Stocks, Aquaculture, and Mangrove Coastal Protection Services

MAIN MESSAGES

- Marine fish stocks play a key role in supporting local economies and food security. However, they have been overexploited over the last 25 years, leading to dramatic declines in the real asset value of marine fish stocks. The real value of marine fish stocks has dropped by more than 25 percent since 1995, equivalent to a $70 billion decline in chained 2019 US dollars.
- Mangroves provide a range of ecosystem services, one of the most critical being that they protect people and assets along the coastline. While the nominal value of these protection benefits increased dramatically between 1995 and 2020, in real terms, mangrove wealth still declined due to the continued loss in mangrove cover.
- More spatially disaggregated and detailed data are needed to further improve our measurement of these critical assets and help inform management decisions and policy choices aimed at restoring and sustainably managing blue natural capital.
- Aquaculture assets have not yet been included in CWON, but they could be, using a resource rent approach. Asset values from aquaculture are likely to be positive, significant, and growing as production continues to expand. However, there are major data constraints as the necessary information on operating and capital costs is rarely available. This could be addressed by the establishment of a systematic and integrated data collection system consistent with the System of National Accounts (SNA) and the System of Environmental-Economic Accounting (SEEA) methodologies, and supported by an aquaculture economics community of practice comprising national statisticians, technical specialists, economists, and regulatory authorities.



INTRODUCTION

Blue natural capital is critical to coastal nations around the world. Two of the most critical services provided by coastal and ocean ecosystems are food production and coastal storm protection, which support lives and livelihoods. There are two marine systems for which there are sufficient data to assess trends in national wealth over time: marine fish stocks and mangroves. The previous CWON report considered marine fish stocks and mangroves for the first time (World Bank 2021). These analyses are advanced here by producing real wealth estimates for both assets using a new methodology that accounts for both changes in the physical quantities—for example, the total weight of fish of a specific taxon (species) in a fishery or the hectares of mangrove forest—and real price changes (for more detail, see chapter 2). This has significant implications for the real wealth estimates, which will now directly capture any degradation in blue natural capital. The potential to include aquaculture in future CWON reports is also assessed.

Marine fish stocks and fisheries represent an important component of renewable natural capital in coastal nations, especially in small island states and places where communities rely on healthy oceans for food and livelihoods (Stuchtey et al. 2023; World Bank 2021). Globally, 1 out of 10 people rely on fisheries and aquaculture for their livelihoods (FAO 2016). However, blue natural capital linked to fisheries is deteriorating around the world due to multiple factors, but the one affecting the wealth of marine fish stocks the most is overexploitation (World Bank 2021; Srinivasan et al. 2010). As a renewable natural resource, the asset lifetime and stream of future benefits from marine fish stocks are potentially infinite if the fish stock is allowed to regenerate naturally (Sumaila 2021).

However, if marine fish stocks are overexploited beyond natural regeneration, the future stream of economic benefits and resource rent will decline over time as if these were a nonrenewable natural resource (Lam and Sumaila 2021; World Bank 2021).

Part of the solutions for restoring the health of ocean ecosystems and preventing this resource degradation is to account for the values of marine fish stocks in national wealth accounts. Despite their importance, marine fish stocks are generally measured and assessed based on data that are often incomplete, inaccurate, or limited. This type of blue natural capital includes the value of these assets in the broader macroeconomic framework, which can help decision-makers understand its contribution to wealth and assess the risks of overexploiting marine fish stocks.

In contrast to stagnating catches from marine capture fisheries, global aquaculture production has grown rapidly over the last 25 years, reaching a total nominal value of $281.5 billion in 2020 (FAO 2022). This included 87.5 million tonnes of aquatic animals (such as fish, shrimp, and bivalve mollusks) and 35.1 million tonnes of algae. The growth of aquaculture has helped meet growing demand for fish, which has more than doubled from an average of 9.9kg per capita in the 1960s to 20.2kg per capita in 2020, with total aquatic animal production expected to grow by another 14 percent by 2030 (FAO 2022). However, despite being an increasingly important source of food, income, and employment in many parts of the world (Little, Newton, and Beveridge 2016), aquaculture is not yet included in CWON.

A key challenge is that aquaculture is a complex industry that encompasses a broad range of production systems. These include floating cage-based finfish aquaculture, pond and tank-based finfish and shrimp, as well as various bivalve shellfish and seaweed growing systems. In addition, the systems are situated in marine coastal waters, along coastlines, in river estuaries, and in inland freshwaters, such as lakes and rivers, and may use water supplied by agricultural irrigation systems. Aquaculture is also carried out at a wide range of production intensities, from highly productive tank or cage-based systems where species such as salmon or marine finfish must be fed protein- and energy-rich diets, to pond-based systems growing carps or tilapia where natural food comprises a high proportion of the nutritional requirements, as well as unfed systems for filter-feeding mollusks and seaweeds. Consequently, data requirements are very high, as detailed data are needed on each of these production systems, which vary across countries. For example, aquaculture in most Asian countries includes a diverse range of species groups, whereas countries such as Chile, Norway, Ecuador, and Egypt are more specialized, growing relatively few species.

This chapter discusses potential methodologies for including aquaculture in CWON and the likely scale that aquaculture might comprise in blue natural capital accounts. Including aquaculture assets in CWON is not challenging from a conceptual point because a residual value method (RVM)/net present value (NPV) approach can be readily applied, as recommended by the SNA and SEEA. However, there are significant data constraints, as the required information on operating and capital costs is rarely reported in publicly available datasets. Most of the estimates for the pilot accounts presented in this chapter are thus based on research results and information from key contacts.

Lastly, mangroves—and the ecosystem services they provide—are of critical importance for biodiversity and coastal communities at both local and global scales (Leal and Spalding 2022; Bunting et al. 2022; Kauffman and Donato 2012; McLeod et al. 2011). Globally, they sustain 4.1 million small-scale fishers (Ermgassen et al. 2021), buffer coastlines against storm surges, provide $65 billion per year in flood protection (Hagger et al. 2022), and mitigate climate change by storing an estimated 8.5 gigatons of carbon (Hagger et al. 2022; Richards et al. 2020). These benefits in turn support coastal communities and boost economies (Spalding et al. 2014).

This chapter first presents the methods and data sources used to produce value estimates for each asset. Next, it discusses the respective findings and concludes with suggestions for future work and further methodological improvements.

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197 The industry is dominated by China, which represented 60.3 percent of global aquaculture value in 2020, followed by India, Vietnam, Indonesia, Chile, Norway, Bangladesh, Japan, Ecuador, Thailand, Egypt, and the Republic of Korea (FAO 2022).

ESTIMATING THE WEALTH OF MARINE FISH STOCKS, AQUACULTURE, AND MANGROVE COASTLINE PROTECTION SERVICES

Marine fish stocks

To estimate the value of marine fish stocks, the RVM/NPV approach is used, as recommended by the SNA and SEEA (for more detail, see chapter 2). To compute the value of an asset, such as marine fish stocks, the NPV of the stream of rents needs to be computed. As a first step, resource rent for marine fish stocks needs to be estimated, which requires information on fish stocks, catch volumes by species, fishing costs, landed value, and price. Catch, landed value, and fishing cost data are obtained from the Sea Around Us (SAU) reconstruction database,[198] as well as the fishing cost database from the Fisheries Economics Research Unit (FERU) at the University of British Columbia. These databases build on data from the Food and Agriculture Organization of the United Nations (FAO) and include estimates of catch and economic indicators not always reported in the FAO database. SAU and FERU allow for more detailed and granular data by (i) disaggregating catch and landed value into four major categories, while FAO reports only total catch; (ii) including spatialized catch and landed value; and (iii) including the cost of fishing to correctly estimate resource rent.

Catch data[199] in weight are disaggregated into fishing entities by different taxa, fishing gear types, distant-water fleets, domestic fleets, catch types (landings and discards), and fishing sector (industrial, subsistence, artisanal, and recreational). Ex-vessel prices refer to the price fishers receive directly for their catch when it enters the supply chain (Sumaila et al. 2021). The ex-vessel prices data are reported in current and constant US dollars for each exploited marine taxon and country and can be matched to catch data to estimate the landed value. Ex-vessel prices are expanded from 2010 to 2018[200] by assuming constant ex-vessel prices for each taxon and country and transformed to 2020 constant US dollars using price deflators. By combining the catch data with the ex-vessel price of each marine taxon, the landed values can be estimated for different fishing countries at different spatial locations. FAO data were used wherever possible, with SAU catch data used to fill gaps. Finally, the FERU's fishing cost data are arranged by year, fishing entity, gear type, and fishing sectors. Similar to most of the variables or indicators in the SAU database, fishing cost data points were obtained from gray literature, government and consultant reports, FAO, and other sources (Lam and Sumaila 2021).

Marine fish stocks might generate positive rents but be managed unsustainability, reducing the time horizon over which the resource could generate rents. Rent from marine fish stocks depends heavily on the abundance of fish biomass. Essentially, without fish there will be no fisheries and no fish jobs or fish dollars. If fishing efforts are at the maximum sustained yield, fish stocks will be able to regenerate naturally, and future rent will not be compromised. However, if fishing efforts exceed the maximum sustained yield, marine fish stocks are transformed into a resource much more akin to an exhaustible mineral resource, which will be unable to regenerate and will decline over time until collapse. For this report, to produce the core wealth account for fisheries for all countries in the database, the economic value of fisheries in 2020 is assumed to be the net present value of rents over 100 years, assuming rents remain constant at the 2020 rent. Scenario analysis could be applied to estimate future rents based on the expected sustainability of fisheries in each country or anticipated policy changes. However, for practicality and consistency with other accounts such an analysis is not applied when computing the real value of fish stocks. Future data users can then use the CWON data as inputs in their own scenario analysis as they aim to answer specific policy questions.

Finally, to compute real wealth estimates of marine stocks using the new methodology, a measure of the fish stock

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[198] www.seaaroundus.org.

[199] The analysis focuses on total catch by a given fishing country, which includes a country's own exclusive economic zone as well as foreign exclusive economic zones if the country's fishing fleet fishes in international waters. Total catch is inclusive of reported and unreported catches by the artisanal, subsistence, and industrial sectors intended for direct human consumption and for processing into fishmeal and fish oil.

[200] The complete 1995–2018 series is extrapolated to estimate the values for 2019 and 2020.

biomass or “volume” is needed to measure its status—for example, whether the fish stock is healthy, close to healthy, or in a bad condition. Biomass estimates of major exploited species in a country’s exclusive economic zones were derived by the SAU initiative by applying a suite of methods to reconstruct fisheries catches for the 1950–2018 period and complement them with stock assessments performed previously by others. The total volume of fish stocks from all exclusive economic zones is then collapsed at the country level and filtered by the certainty of the reported data, where only observations with reliability scores of 3 and 4 (meaning higher data reliability) are used.

Aquaculture

CWON asset account methodologies, where possible, should align with the internationally accepted statistical standards laid out in the 2008 SNA and its extension, the SEEA (United Nations 2008; United Nations et al. 2021). While aquaculture is briefly mentioned in the SNA as a type of production alongside livestock, it is more specifically referenced at several points in the 2021 SEEA-EA publication, where it is included in the SEEA-EA reference list of selected ecosystem services as a biomass provisioning service. SEEA-EA outlines a range of approaches that can be used to value ecosystem services including for agricultural production, such as RVM/NPV, where the direct operating and input costs associated with producing an agricultural output (such as fuel, fertilizer, labor, and produced assets) must be deducted from the value of the output to isolate the value of the ecosystem services. Depending on the scope of the data, the estimated residual value provides a direct value that can be recorded in ecosystem accounts.

While this indicates that it should be possible to use the RVM/NPV to estimate the value of ecosystem services for aquaculture, it is an indirect approach and is prone to error if based on insufficient or inaccurate data (United Nations et al. 2021). The main global database for aquaculture is the FAO system, which receives inputs from each country (FAO 2023). This provides information on aquaculture production quantity and value in each country, broken down by species and environment. An RVM/NPV approach requires additional information on operating and capital costs not collected by most national statistical agencies and not included in the FAO database. As explained in the technical report (Dickson et al. 2024), a pilot account approach was adopted where resource rents from individual countries (Norway, Egypt, Ecuador, Japan, Bangladesh, and Indonesia) and species (salmonids, tilapia, shrimp, carps, pangasius, yellowtail, seabream, milkfish, scallops, oysters, and seaweed) were estimated using available information. Only Norway provided sufficient official data to estimate resource rents over the period 1995 to 2020. In the other pilot countries, estimates were based on research studies or on contributions from organizations and consultants with extensive experience in those countries.

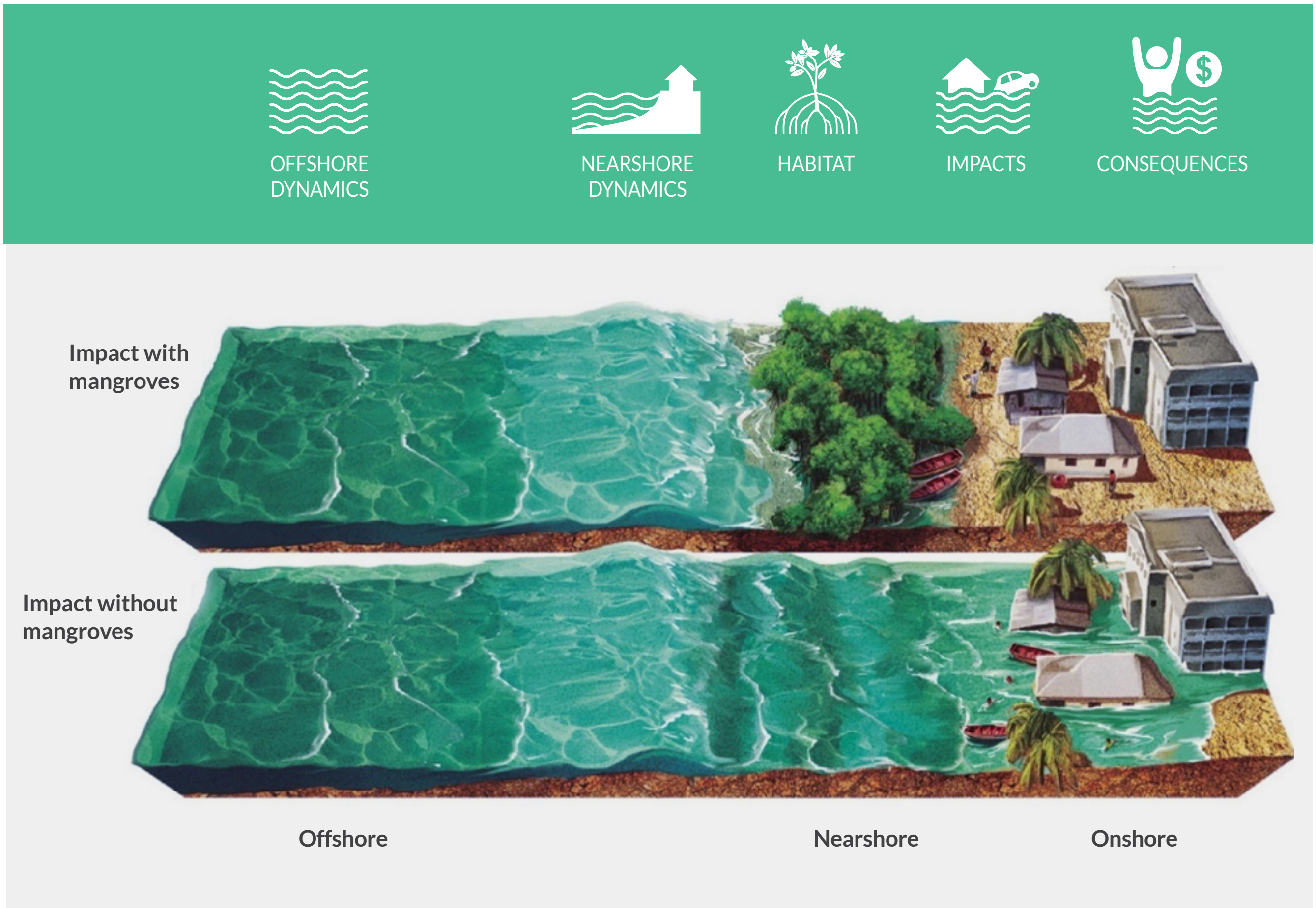
Mangrove coastal protection services

Mangroves provide coastal protection by reducing flooding and the resulting damage to produced capital and populations that would occur from storms if mangroves were absent (Figure 8.1). The “averted damage” valuation approach is widely used by economists and provides a rigorous foundation for estimates of flood risk and habitat benefits (Barbier 2015; Beck and Lange 2016; Pascal et al. 2016; Van Zanten, Van Beukering, and Wagtendonk 2014). It also provides an integrated quantitative framework with process-based models and statistical tools consistent with national accounting to capture risk and national benefits (Figure 8.1).

The averted damages approach combines multiple commonly used models to assess storm hazards (waves and surge), flooding impacts, and socioeconomic consequences. The hazard and impacts are estimated using a combined set of process-based storm and hydrodynamic models, which are commonly used by engineers and risk modelers (Beck et al. 2024). These models identify the area and depth of flooding under cyclonic and non-cyclonic storm conditions and can be used to conduct scenario analysis with and without mangroves for different storm frequency events. Then, the flood maps are overlaid on population maps and produced capital stock data to determine exposure. Lastly, the flood depth and exposure data are combined, considering depth damage functions, to compute the population and capital stock at risk of flood damages as well as the avoided damages (that is, the benefits provided by habitats in reducing flood risk to people and produced capital).

FIGURE 8.1

Key steps and data for estimating the flood protection benefits provided by mangroves



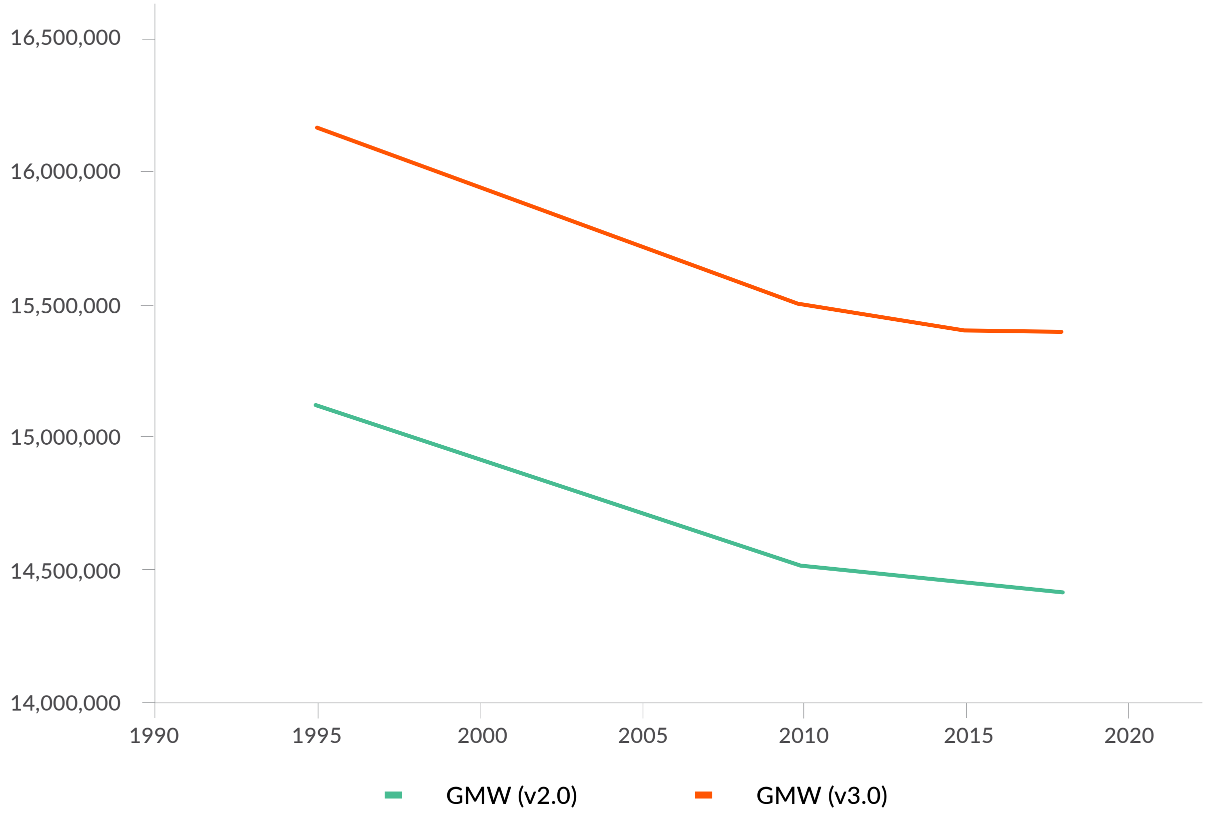
Source: Figure 2.1 in Menéndez et al. 2024.

This approach follows the same methodology used in CWON 2021 but uses new and updated past global mangrove distribution data from Global Mangrove Watch (GMW 3.0; Bunting et al. 2022). While the past mangrove data did not change greatly (1996–2015), all prior year models were rerun. The results provided here represent improvements on the prior CWON report in addition to the most recent yearly estimates (to 2020). The most significant difference in these datasets is that the improved GMW 3.0 shows a consistently greater global coverage than GMW 2.0 (about 7 percent greater, Figure 8.2). To consistently assess mangrove benefits over time, the flood models were rerun for all years using the new data, and new assessments of risk and benefits were developed.

Despite observing changes in the total area of mangroves, these changes had limited impact on the results. The crucial factor driving variations in coastal flooding is the cross-shore width of the mangrove forest, and this distance did not change greatly even when there were changes in total mangrove area.

FIGURE 8.2

Differences in global mangrove cover between GMW 2.0 and GMW 3.0



Source: Figure 3.1 in Menéndez et al. 2023.
Note: Mangrove cover is reported in hectares.

GLOBAL TRENDS OF BLUE NATURAL CAPITAL

Marine fish stocks

The global value of marine fish stocks represents only a fraction (less than 1 percent) of the world's total renewable natural capital in nominal terms. This is in part due to the large number of landlocked countries that do not have access to this resource and, thus, record no wealth from marine fish stocks. However, in smaller coastal countries, marine fish stocks can be an important source of wealth. For example, almost half of Malta's renewable natural capital comes from these marine resources.

Moreover, for those countries with access to marine fish stocks, the real value of the asset considerably declined between 1995 and 2020. Due to the overexploitation of this resource and the negative effects of climate change, the biomass of marine fish stocks has declined (Cheung et al. 2021), resulting in declines in fishery revenues and rents (Sumalia et al. 2011, 2019; Lam et al. 2020). Hence, the decline in fish stocks has impacted global wealth,[201] which has dropped from $54 to $29 chained 2019 US dollars per capita. This means that the world has lost about one-quarter of its wealth from marine fish stock in 25 years (Figure 8.3), 3 times faster than mangroves and 10 times faster than timber. Some countries have seen more dramatic declines, where large economies, including Kenya, Pakistan, Saudi Arabia, Senegal, and Tanzania, have lost more than 60 percent of their per capita value generated by their marine fish stocks.

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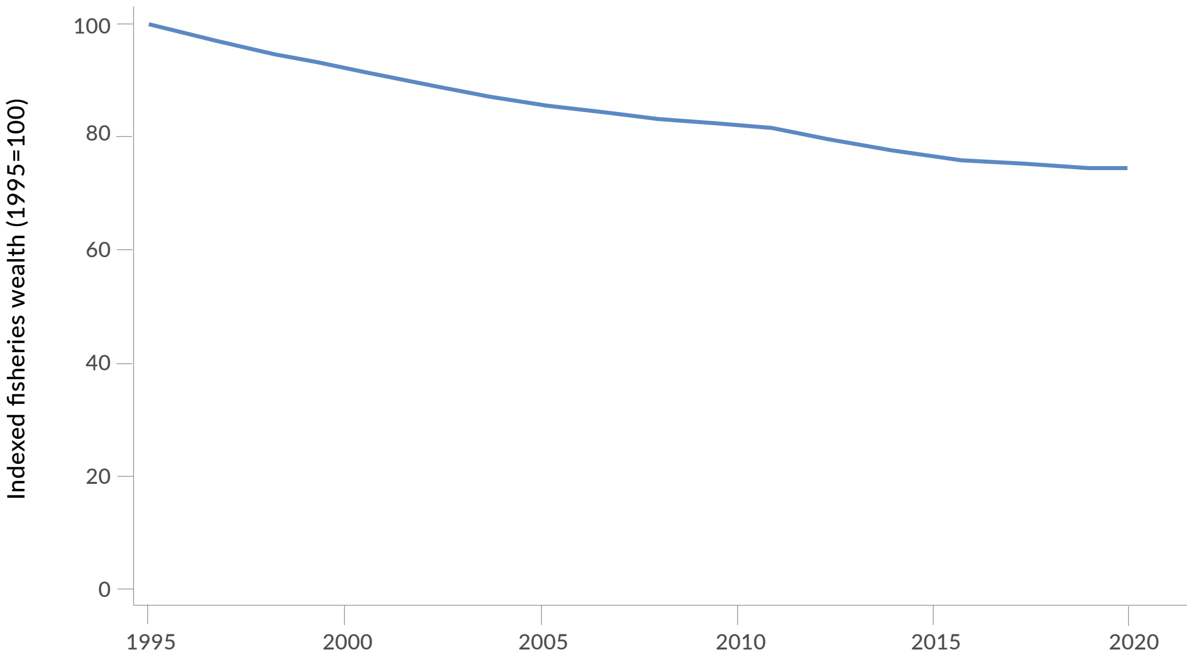
[201] Unless otherwise indicated, all wealth estimates are in real terms and are reported in chained 2019 US dollars.

FIGURE 8.3

Global marine fish wealth, indexed to 1995, 1995–2020

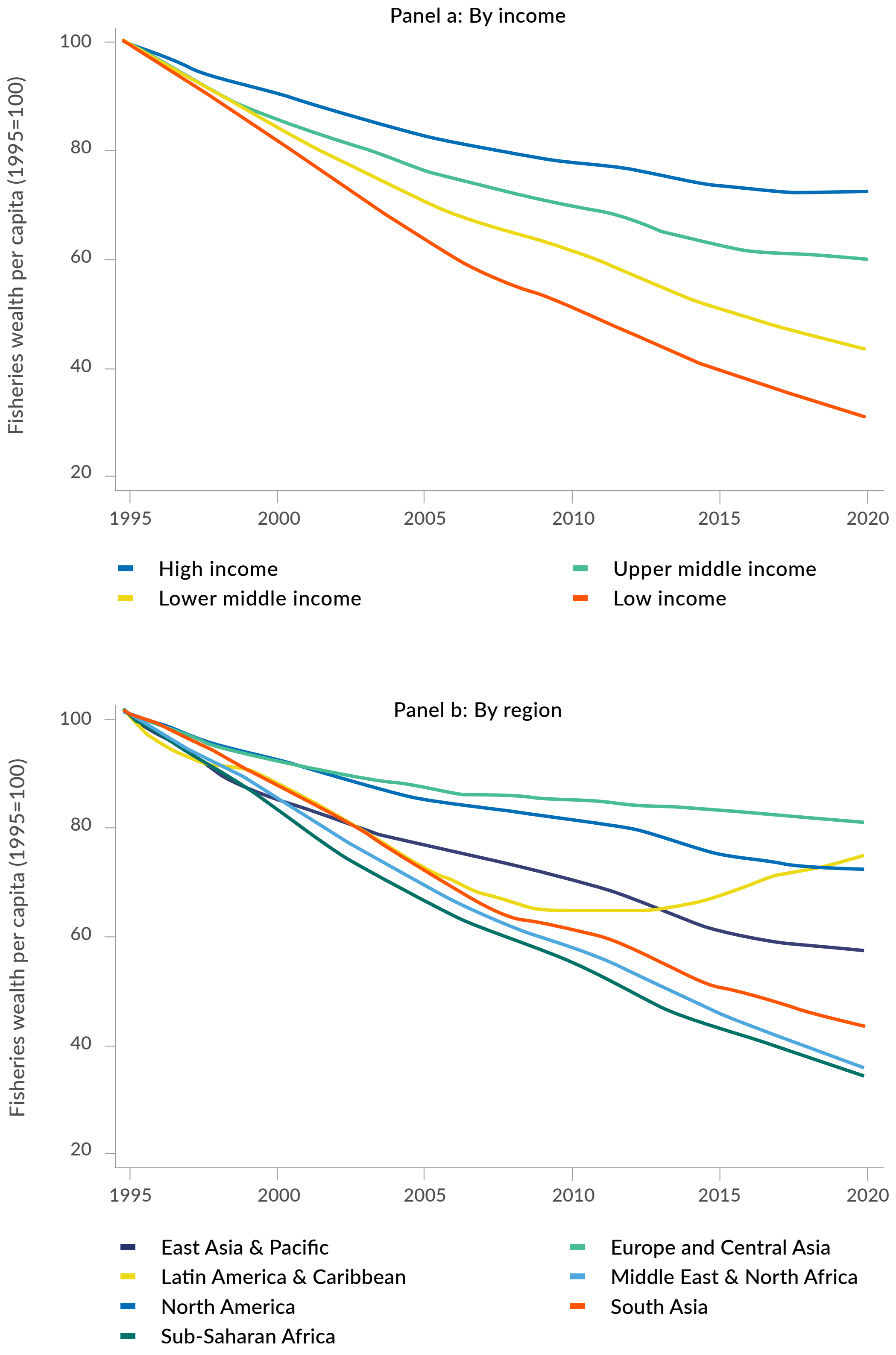


Source: World Bank staff estimates.
Note: Wealth is measured in chained 2019 US dollars.

The decline in global wealth from marine fish stocks is not the only concern, with CWON 2024 revealing significant inequalities across income groups. People living in high-income countries hold more than double the marine fish wealth of people living in lower- and upper-middle-income countries. The situation for low-income countries is even more concerning. On average, low-income countries have lost around one-third of their wealth per capita from marine fish stocks, going from $12 to $4 in chained 2019 US dollars between 1995 and 2020. At the same time, inadequate fisheries management in lower-middle-income countries has led to unsustainable catch practices that accelerated the depletion of marine fish wealth (Panel a, Figure 8.4; see also Englander 2019 and Hilborn et al. 2020). Wealth from marine fish stocks has not been depleted at the same rate across regions. Coastal countries in the Middle East and North Africa and in Sub-Saharan Africa have experienced the fastest wealth depletion rate, losing almost two-thirds of their wealth per capita from marine fish stocks in just a quarter of a century. The situation in other regions is more optimistic. Europe and Central Asia and Latin America and the Caribbean, on average, have about the same wealth from marine fish stocks now as they had in 1995 (Panel b, Figure 8.4).

FIGURE 8.4

Per capita wealth from marine fish stocks, by income and region, 1995–2020



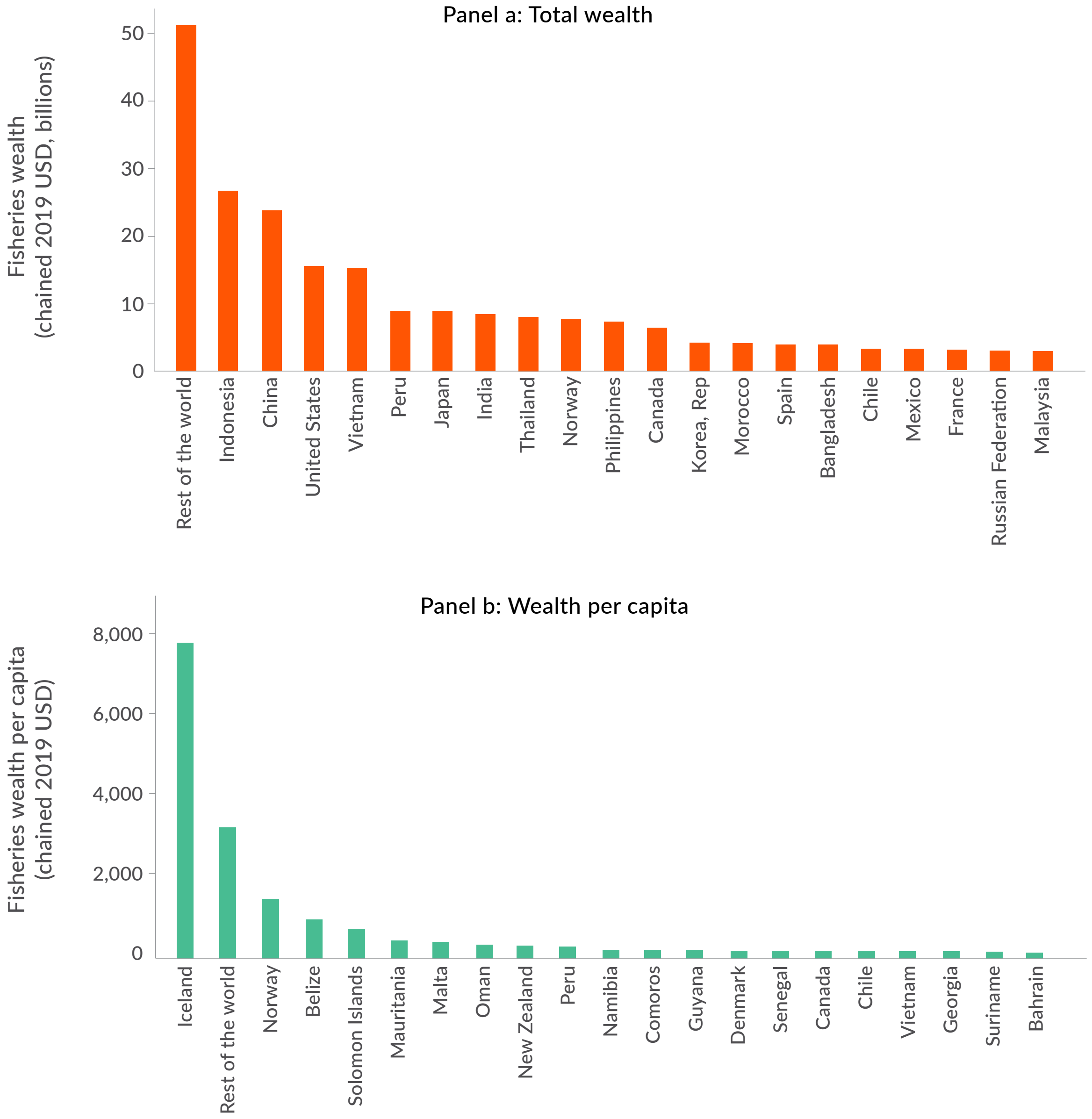
Source: World Bank staff estimates.

Note: Wealth per capita is measured in chained 2019 US dollars.

Wealth in marine fish stocks is highly concentrated in a few countries. There are 20 countries that hold more than two-thirds of the wealth (Panel a, Figure 8.5), with about 50 percent of the value of all the world's marine fish stocks concentrated in four countries: Indonesia, China, the United States, and Vietnam. Despite the relatively high concentration of wealth in a few countries, richness in marine fish stocks can be found all over the world and in all regions and income groups, from Peru in Latin America to Malaysia in Asia, and from Morocco in North Africa to Norway in Europe. In per capita terms, Iceland has the largest wealth in marine fish stocks available per person, followed by Norway and other coastal nations with smaller territories, including Belize, the Solomon Islands, and Malta (Panel b, Figure 8.5).

FIGURE 8.5

Wealth in marine fish stocks, top 20 countries, 2020



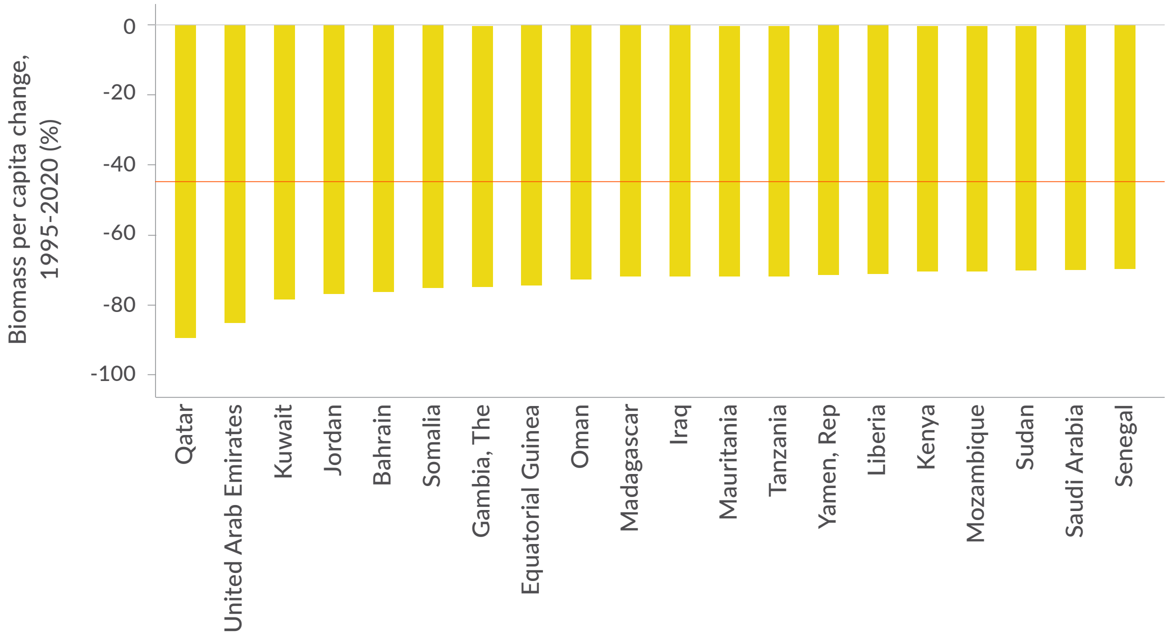
Source: World Bank staff estimates.

Note: Wealth is measured in chained 2019 US dollars.

Among these countries with vast wealth in marine fish stocks, there are countries whose resources are being depleted much faster (Figure 8.6). Many of these countries are found in Sub-Saharan Africa and in the Middle East and North Africa, where renewable natural capital could be scarce. For example, Oman and Mauritania, which hold one of the top 10 largest amounts of marine fish stock wealth per capita in the world, lost more than 70 percent of fish biomass between 1995 and 2020, which puts at risk the sustainable future of an important part of their renewable natural capital.

FIGURE 8.6

Countries with the top 20 largest loss of fish biomass per capita, 1995–2020



Source: World Bank staff estimates.

Note: The red line shows the global average of marine biomass loss of 45 percent. Biomass is measured in tons.

AQUACULTURE

The resource rents were computed for several pilot countries to illustrate the applicability of the RVM/NPV approach to aquaculture and gauge its economic importance. The first pilot country is the salmon and trout farming industry in Norway, for which resource rent could be estimated by drawing on detailed information on the aquaculture industry's operating and capital costs published by the Norwegian Directorate of Fisheries website. These data were combined with FAO information on production quantity and value to estimate resource rents for 1995 to 2020 (Table 8.1). The estimates in Table 8.1 indicate that the Norwegian salmonid industry has been generating significant resource rents in recent years, in line with recent research by Greaker and Lindholt (2021).[202] The profits being generated by salmon farming companies were noted by the Norwegian government, and following several months of negotiations, an extraordinary tax was applied to large companies with promises that this would result in increased resources for areas of the country where fish farms are located.

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[202] Greaker and Lindholt (2021) estimate that while resource rent was around zero until 2010, over the most recent 10-year period, resource rent averaged around 14 billion Norwegian kroner ($1.8 billion) per year.

TABLE 8.1

Resource rent estimates for Norwegian salmon and trout aquaculture, selected years, 1995–2020

YEAR	1995	2020	2005	2010	2015	2020
Production (t)	276,510	448,267	645,080	994,211	1,376,353	1,484,697
Output ($ x 1,000)	**1,022,255**	**1,374,495**	**2,099,890**	**5,040,216**	**5,760,477**	**7,282,847**
Intermediate consumption (-)	**724,653**	**858,398**	**1,540,937**	**3,274,142**	**3,697,225**	**4,014,363**
Seed ($ x 1,000)	186,264	148,192	197,020	401,977	457,414	729,076
Feed ($ x 1,000)	403,792	532,655	1,007,938	2,154,124	2,429,858	2,463,965
Fuel and transport ($ x 1,000)	134,597	177,552	335,979	718,041	809,953	821,322
VALUE ADDED (=) ($ x 1,000)	**297,602**	**516,097**	**558,953**	**1,766,073**	**2,063,253**	**3,268,485**
Compensation of employees (-)	184,640	118,996	148,883	364,894	413,796	592,208
GROSS OPERATING SURPLUS	**112,972**	**397,100**	**410,071**	**1,401,179**	**1,649,457**	**2,676,277**
Depreciation (-)	9,411	59,569	85,976	217,664	310,340	522,548
Return on fixed assets (-)	2,936	14,452	20,102	49,210	72,295	127,012
RESOURCE RENT ($ x 1,000)	**100,615**	**323,079**	**303,993**	**1,134,305**	**1,266,822**	**2,026,717**

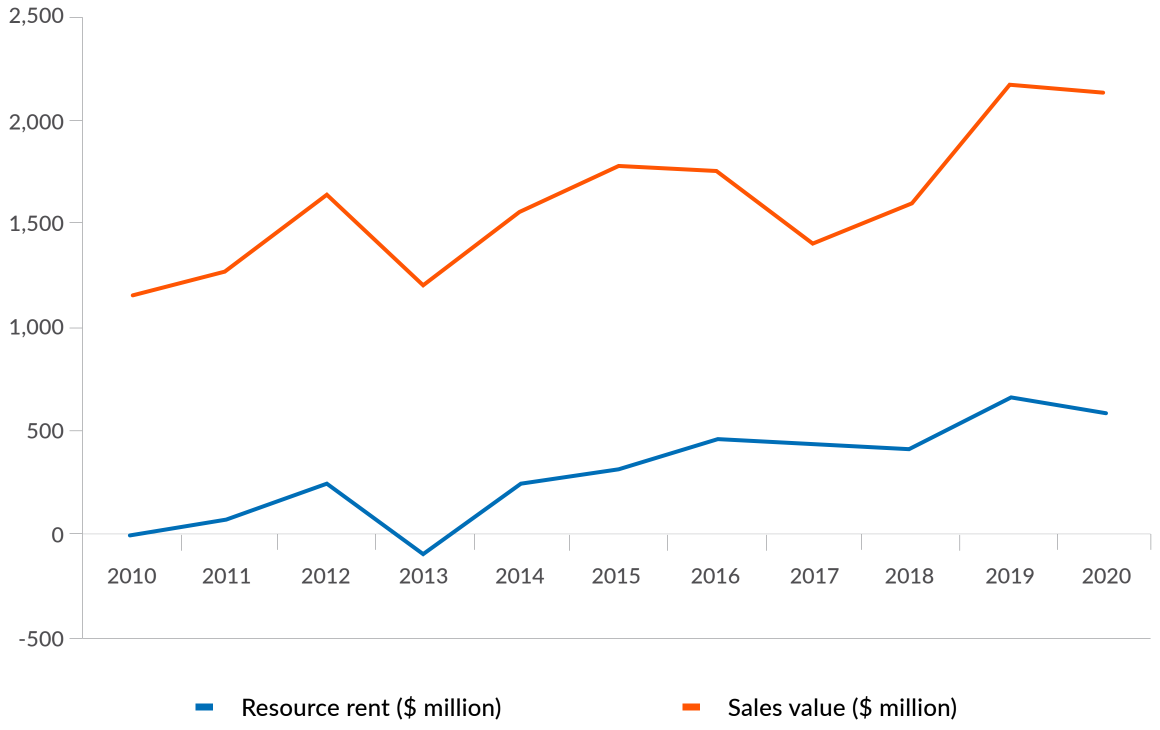
Source: https://www.fiskeridir.no/English/Aquaculture/Statistics/Atlantic-salmon-and-rainbow-trout.

Note: All data are reported in current US dollars.

The second pilot study was conducted for **Egypt**, which has developed a significant tilapia and mullet production industry based on small-scale fish farmers operating earth ponds fed by water from irrigation systems. Resource rents were estimated over the period 2010 to 2020 based on production quantity and value from FAO, combined with estimates from WorldFish Egypt (A. Nasr-Allah, pers. comm.). As shown in Figure 8.7, this analysis shows that Egyptian tilapia and mullet aquaculture generated significant resource rents, estimated at about $500 million per year over the last five years. It should be noted that this is based only on tilapia/mullet polyculture in the main aquaculture zones and does not include carp culture, most of which takes place in government farms or marine aquaculture, both of which have very different operating cost structures and take place in areas beyond the main zones. The low levels of resource rent during 2011–2014 may be related to a period of social unrest when there was considerable economic uncertainty. Fluctuating exchange rates and shortages of foreign currency restricted imports such as soya, an essential ingredient in aquaculture feeds. The dip in production value from 2016 to 2017 was due to a rapid fall in the value of the Egyptian pound against the US dollar.

FIGURE 8.7

Egyptian tilapia/mullet aquaculture resource rent and sales value, 2010–2020



Sources: FAO 2023a and A. Nasr-Allah, WorldFish Egypt (pers. comm.).
Note: The resource rent and sales value are reported in current $ million per year.

Estimation of aquaculture resource rents in Egypt highlights the challenge posed by collecting data from large numbers of smallholder farmers. Most small-scale fish farmers do not keep accurate records and are not required to report production data to regulatory authorities. The main operating cost for Egyptian fish farmers is feed, while labor and seed costs are relatively low. Most fish farms are family-operated, informal businesses that depend on credit from feed companies and wholesalers to cover their annual operating costs. Wholesalers recover their own credit and credit advanced by the feed companies when they sell the fish from each farmer at the end of the growing season. Aquaculture production has grown in Egypt because value chain actors have been able to invest and make profits (Dickson et al. 2016). This profitability is likely to continue as long as regulations place restrictions on the area available for aquaculture while the domestic market continues to expand.

Ecuador was selected as the third case study, given that it has played a major role in the global success of saltwater, pond-based shrimp aquaculture. Despite the importance of shrimp aquaculture to Ecuador, there appears to be almost no published data on operating or capital costs for shrimp farms. A resource rent estimate for shrimp production in Ecuador in 2020 was based on production quantity and value information from FAO (FAO 2023), and operating and capital cost estimates from a key contact who worked in the industry for several years (P. Buike, pers. comm.). It shows strongly positive resource rents of $1.5 billion being generated by the sector in 2020, equivalent to over $2 per kilogram of production.

Japan is a marine aquaculture pioneer, with records of oyster, marine finfish farming, and seaweed cultivation going back to the 17th century. The Japanese Ministry of Agriculture, Fisheries and Forestry (MAFF) publishes sample data each year on the operating costs for aquaculture subsectors (MAFF 2022). Together with FAO data on Japanese aquaculture production quantity and value (FAO 2023), excerpts from the MAFF data were used to calculate resource rent estimates for yellowtail, sea bream, scallops, oysters, and seaweeds in 2020. These indicate negative resource rents for yellowtail (-$305 million), sea bream (-$96 million), and oysters (-$525 million), while resource rents for scallops ($287 million) and seaweeds ($619 million) were positive.

This preliminary analysis highlights the variable performance of aquaculture systems within a country. Yellowtail and sea bream have high feed costs, while market prices are probably affected by imports. Japan imports around 40 percent of its seafood, making it the third-largest global importer (Ganapathiraju, Pitcher, and Mantha 2019). This means domestic producers face market competition while Japanese companies have invested in aquaculture production in other countries.

Aquaculture production expanded rapidly in **Bangladesh** from 2.8 million tonnes in 2010 to 6.3 million tonnes in 2020 through the intensification of production systems as well as the conversion of agricultural land into aquaculture ponds (Hasan et al. 2021; FAO 2023a). Two recent research papers focused on the economics of carp polyculture (rohu, mrigal, catla, silver carp, and common carp) in 2019, as well as tilapia culture and pangasius catfish culture in 2017 (Saha et al. 2022; Hossain et al. 2022). Both papers analyzed data from farms that were considered either profitable or not profitable. The data were scaled up to national production levels and used to calculate resource rent estimates of around $785 million for carp culture in 2019, while the figures for pangasius and tilapia resource rents were $300 million and $129 million, respectively, in 2017.

The resource rent calculations extrapolated from the Bangladesh research studies appear to fit with national trends where there has been large-scale investment in carp, tilapia, and pangasius farming. Fish farmers have been very quick to switch between species. Both pangasius and tilapia are relatively new additions to Bangladeshi fish farms. The driving forces behind these switches are the development of new farming systems and support services (fingerlings, feeds, and markets) for those systems, as well as profitability, whether this is to supply local, urban, or export markets (Hernandez et al. 2018).

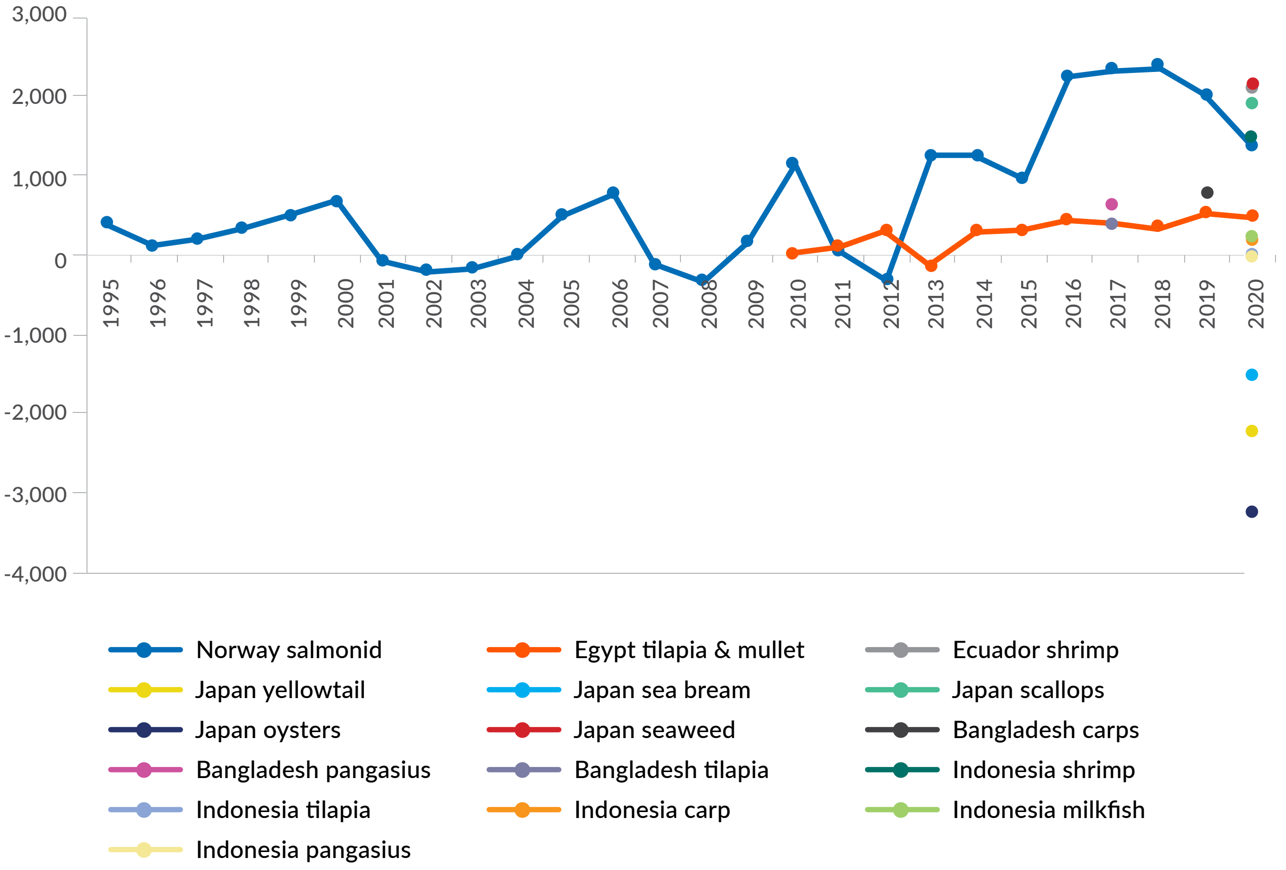
Indonesia has the second-largest aquaculture production industry in the world, worth around $12 billion per year. It has a diverse range of aquaculture systems growing freshwater, marine, and brackish-water species. Preliminary resource rent estimates were developed for shrimp, tilapia, carp, milkfish, and pangasius based on operating and capital cost data supplied by a consultant (R. Tan, pers. comm.) and production figures from FAO. These indicated positive resource rents for shrimp ($1 billion), milkfish ($215 million), and carp ($104 million); a very low resource rent estimate for tilapia ($7 million); and a negative value for pangasius (-$17 million).

Figure 8.8 summarizes the results of resource rent estimates from the pilot countries and species, expressed as resource rent per tonne of production. It indicates highly positive 2020 resource rents for Japanese seaweed ($2,230/tonne), Ecuadoran shrimp ($2,067/tonne), Indonesian shrimp ($1,450/tonne), and Norwegian salmonids ($1,365/tonne, dropping from a peak of $2,368/tonne in 2018). Resource rent estimates for Indonesian tilapia, carp, and milkfish and Bangladeshi pangasius were between $764/tonne and zero, while estimates for Japanese oysters, yellowtail, sea bream, and Indonesian pangasius were negative.

However, these resource rent estimates cannot be used to extrapolate to other countries. For example, resource rents generated by shrimp production in Ecuador were much higher than the equivalent figures in Indonesia, and similar variations in resource rents were apparent between tilapia aquaculture systems in Egypt, Bangladesh, and Indonesia, suggesting that location is an important factor. Each country will have specific costs for feeds, seed, energy, labor, site rental, and maintenance costs, as most aquaculture production is sold locally, so revenue will vary according to local market conditions.

FIGURE 8.8

Resource rent estimates in selected countries and species, 1995–2020



Source: Dickson et al. 2024, forthcoming.

Note: The resource rent estimates are reported in current US dollars per tonne of production.

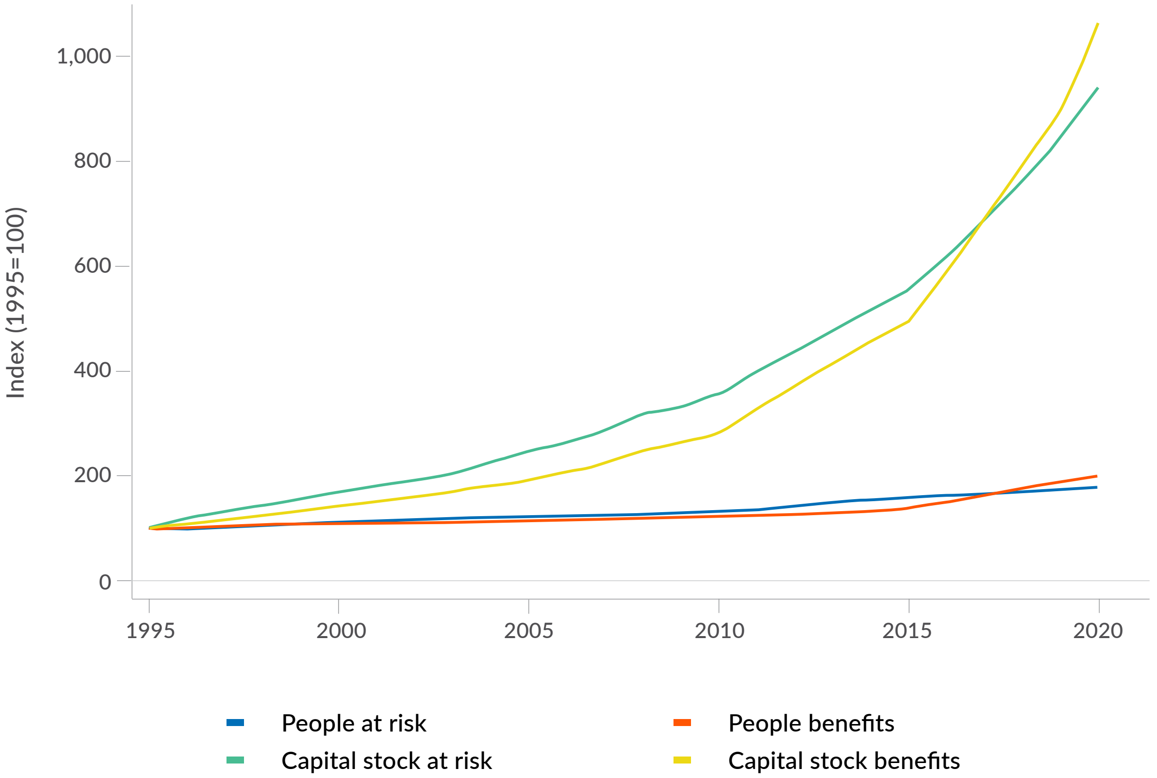
Although direct extrapolation of results from the pilot studies is not possible, they provide indications of expected levels of resource rent. Assuming conservative average resource rent values, the global aquaculture resource rent might be $20 billion. This is equivalent to an asset value of $500 billion in nominal terms, which is more than double the estimated asset value for global capture fisheries of $228 billion in 2020. Using less conservative estimates of aquaculture resource rents (but still within the range of estimates from the pilot study), total resource rents could be as high as $55 billion, equivalent to a total asset value of over $1,300 billion. With global aquaculture production continuing to grow, driven by increased demand and improved efficiency of aquaculture practices, the asset value has the potential for even greater impacts in the future.

MANGROVE COASTLINE PROTECTION SERVICES

As described in Figure 8.1, there are two main components for computing mangrove coastline protection services: the risk and habitat benefit of protected people and produced capital. Both flood risks and habitat risk reduction benefits in nominal terms have increased substantially over the past 25 years, driven by population and economic growth in coastal areas. Between 1995 and 2020, the flood risk and mangrove protection benefit to people almost doubled, while the amount of capital stock at risk and receiving protection benefits more than quadrupled in value (Figure 8.9).

FIGURE 8.9

Value of people and capital stock at risk and receiving risk reduction benefits in current US dollars, indexed to 1995, 1995–2020



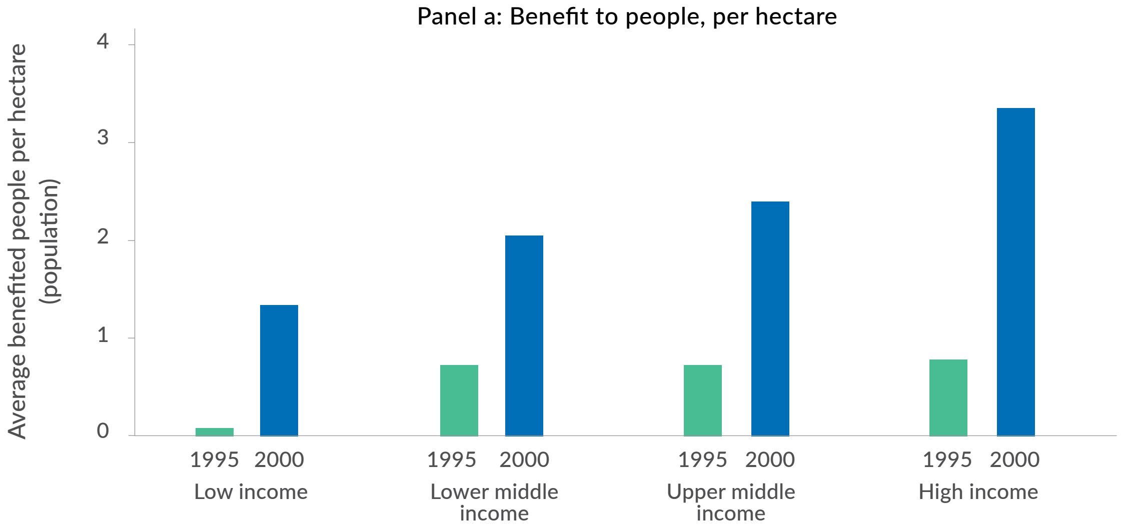
Source: World Bank staff estimates.

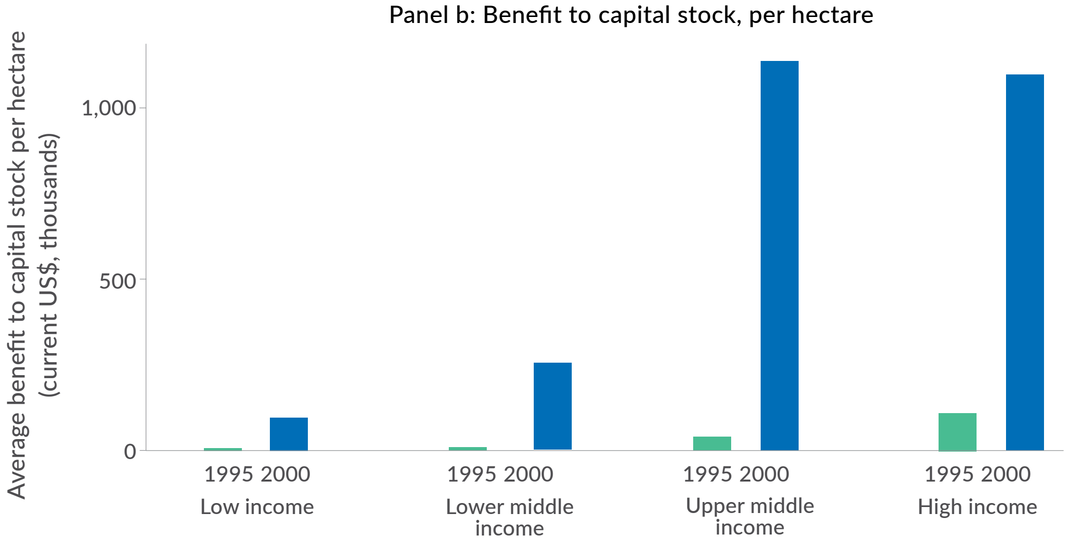
Note: People and capital stock benefits are in units of current US dollars prior to indexing using valuation methods described in the CWON 2024 technical background report (Menédez et al. 2024, forthcoming).

The benefits received by different groups of nations vary greatly. For example, the benefit provided by mangroves of protecting the capital stock in upper-middle- and high-income countries increased by about 1,000 percent on a per hectare basis over the last 25 years (Panel b, Figure 8.10). On the other hand, the number of people living in coastal areas in low-income countries benefiting from mangroves on a per hectare basis increased by more than 3,000 percent over the same period (Panel a, Figure 8.10).

FIGURE 8.10

Per hectare flood risk and mangrove benefits to people and capital stock by income level in nominal terms, 1995–2020





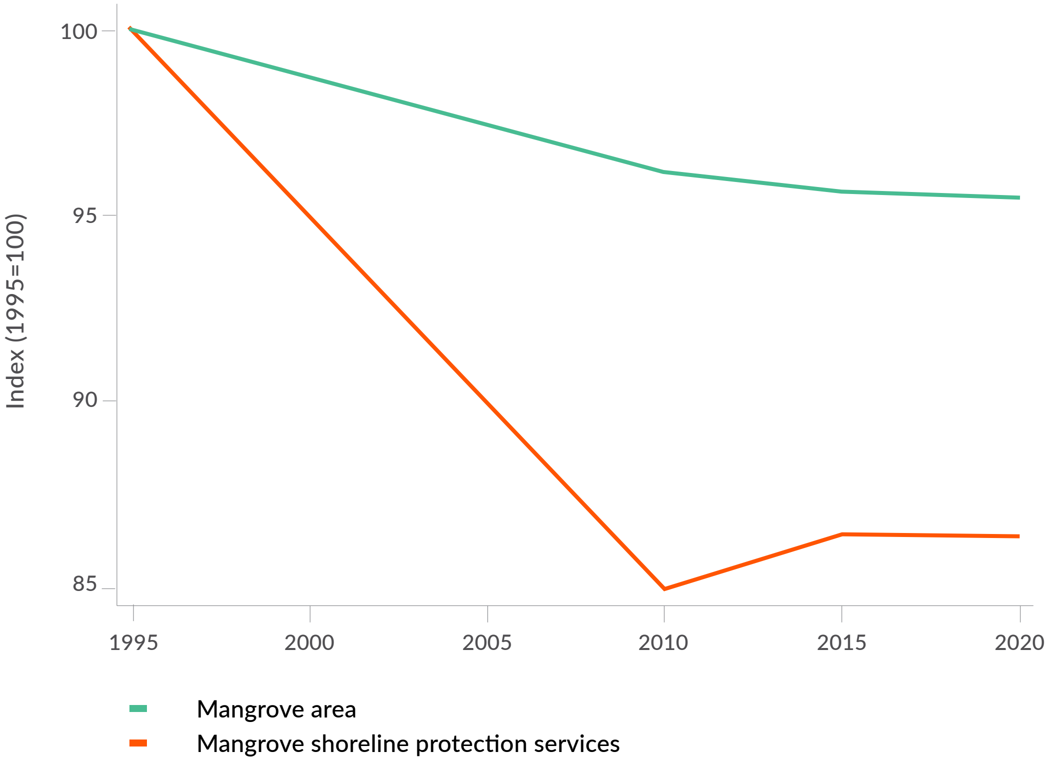
Source: World Bank staff estimates.

Note: Benefit to people and capital stock are measured in current US dollars, as described in the CWON 2024 technical background report (Menédez et al. 2024).

Coastal flood risk has grown dramatically over the past three decades, with increases in overall global population and wealth and concentrated development on coastlines. Concomitantly, the nominal benefits provided by mangroves in reducing that risk has grown, even though mangroves have been lost. However, in real terms, the value of these services has dropped by 15 percent due to an alarming loss of mangrove area in the past 25 years (Figure 8.11). According to Menéndez et al (2023), between 1995 and 2020, the world lost about 700,000 hectares of mangroves, nearly 10 times the size of New York City. In per capita terms, the results show that in 2020, the mangrove area available per person was 30 percent lower than in 1995, which resulted in a decline in the value of mangrove coastline protection services per capita of 37 percent. If this trend continues, our next generations could have less than half of the mangrove coastline protection services value that was available in 1995, leaving them more exposed to flooding and climate change impacts.

FIGURE 8.11

Mangrove area and the value of coastline protection services in real terms, indexed to 1995, 1995–2020



Source: World Bank staff estimates.

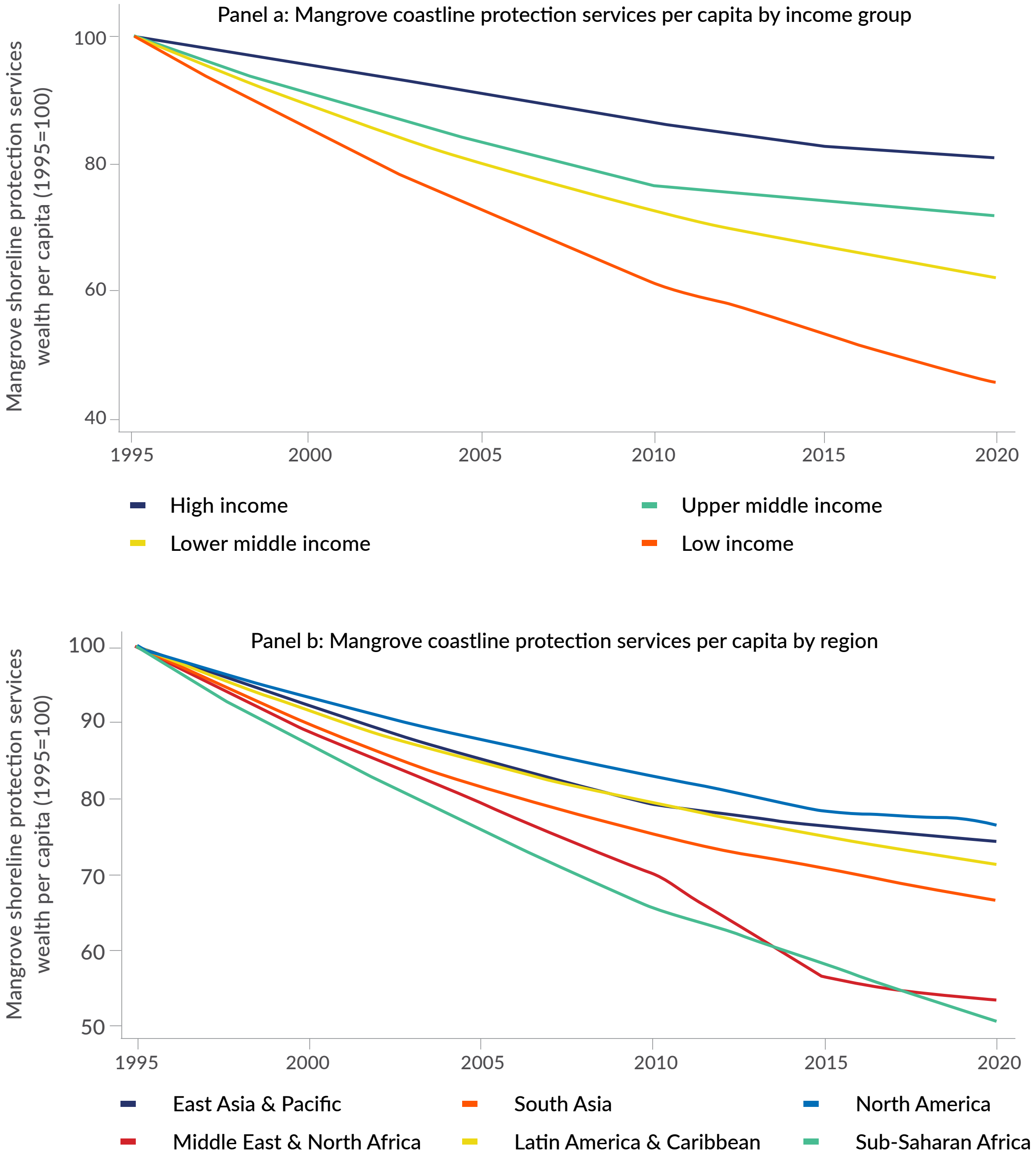
Note: Mangrove area is measured in hectares and mangrove coastline protection services in chained 2019 US dollars.

People in more than 100 nations receive flood protection benefits from mangroves. Mangroves are in greatest abundance in (sub)tropical countries in East Asia and the Pacific, with over 155 million hectares, followed by Latin America and the Caribbean (87 million hectares) and Sub-Saharan Africa (76 million hectares). Despite the richness of mangroves in these regions, the degradation of these natural resources is reducing the value of their coastline protection services per capita. Sub-Saharan Africa and the Middle East and North Africa have experienced the fastest decline, with the mangrove coastline protection services per capita having dropped almost 50 percent in real terms between 1995 and 2020. While the rate of mangrove degradation in the other regions is lower, it is still alarming that the loss of mangrove forests has reduced its coastline protection services per person by one-third over the same period (Panel b, Figure 8.12).

The depletion rate of mangrove coastline protection services value is different at different income levels. The lower the income level, the higher the decline in the value of mangrove coastline protection services per capita. Higher population growth in low-income countries is accelerating the reduction of the available coastline protection services from mangroves, which is now less than 50 percent of what it was in 1995 (Panel a, Figure 8.12). Lack of preservation of this important natural resource in low-income countries is aggravating the situation. Low-income countries have reduced the mangrove forest area by 4 percent, from 1,173 thousand hectares in 1995 to 1,122 thousand hectares in 2020.

FIGURE 8.12

Mangrove coastline protection services value per capita, by income and region, indexed to 1995, 1995–2020



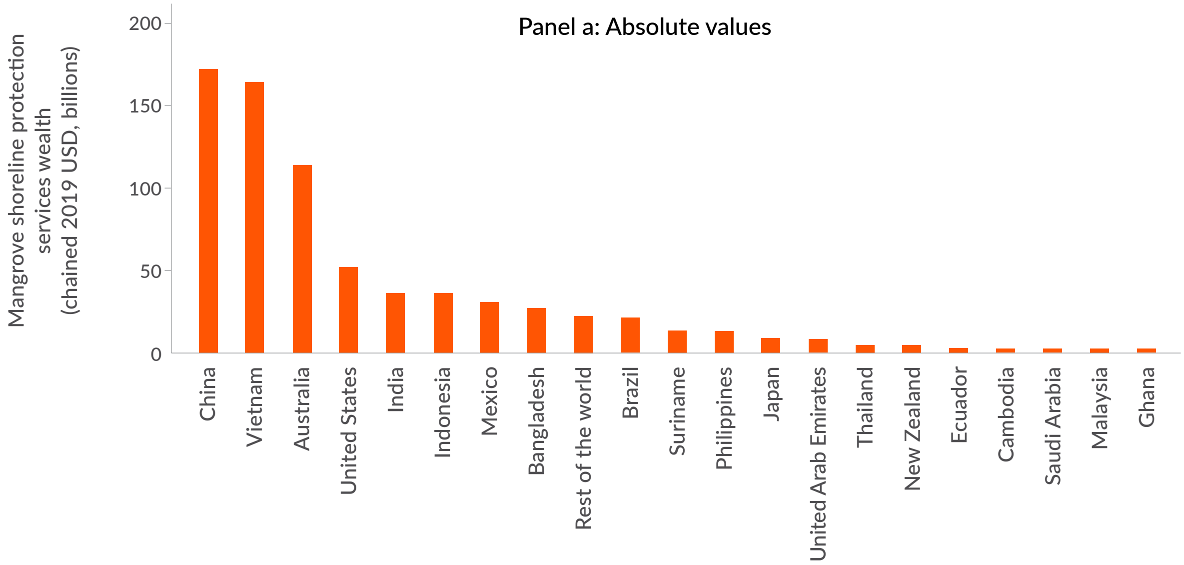
Source: World Bank staff estimates.

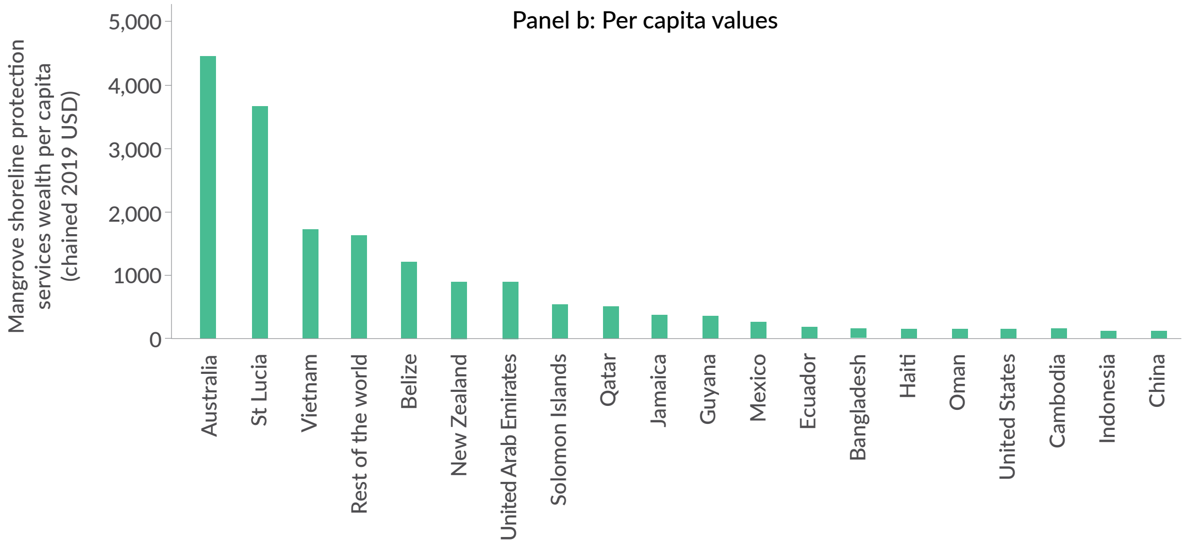
Note: Mangrove coastline protection services in units of chained 2019 US dollars.

The countries with the largest value of mangrove coastline protection services are those with large populations living in coastal areas and vast capital stock built around their shores. Several of these countries are in East Asia and the Pacific, including China, Vietnam, Australia, and Indonesia, but they can also be found in other parts of the world, such as Mexico in Latin America and the Caribbean or Bangladesh in South Asia (Figure 8.13). From these, Australia and Vietnam are the countries with the largest value per capita, since most of their population lives close to their coastlines. There are also other smaller countries, such as St. Lucia and Belize, where the value of mangrove coastline protection services per capita are within the top 10 in the world. For these countries, the preservation of mangroves is even more important, because failing to maintain their current state could impact the value of their natural capital and increase the risks of flooding or vulnerability to climate change shocks.

FIGURE 8.13

Countries with the largest mangrove coastline protection services value, 2020





Source: World Bank staff estimates.

Note: Wealth is measured in chained 2019 US dollars.

CONCLUSIONS

Traditional methods of measuring wealth and economic progress account for built capital and overlook the value of nature's other goods and services. The economic benefits provided by natural resources and ecosystems are undervalued, so their management is adversely affected by a lack of data. This chapter provides an update of the estimates for marine fish stocks and coastline protection services of mangroves, accounting for the blue natural capital of each country. The degradation of stock of these natural capital assets negatively impacts its value, especially the value of marine fish stocks on a per capita basis. Marine fish stocks have experienced the fastest decline among renewable natural capital assets, followed by mangrove coastline protection services. While the value of protection benefits for populations and capital stock along the world's coastlines continues to grow in nominal terms, the real value of the mangrove coastline protection services on a per capita basis is constantly declining due to the insufficient preservation efforts to stop mangrove forest loss.

To prevent this natural resource degradation, it is critical to include their value in national wealth accounting. CWON provides a methodology to include these assets in a macroeconomic framework to guide policy makers on assessing the risks and challenges linked to these resources that could jeopardize economic sustainability. Nonetheless, for both assets, there is scope to improve measurement. For marine fish stocks, data on landed values and assets are limited, and gaps need to be filled through estimation. More systematic data collection is needed to fill these key gaps. For the coastline protection services of mangroves, spatialized capital stock estimates are not available for the entire period covered by the CWON database. More disaggregated data are needed to provide more accurate estimates of the capital stock at risk and protected by mangroves, given the great spatial heterogeneity of built-up infrastructure. Such data are essential to help inform decision-making at the local and country scale to ensure these critical assets are restored and managed more sustainably into the distant future.

The inclusion of aquaculture assets in CWON is not challenging from a conceptual point because an RVM/NPV approach can readily be applied, as recommended by the SNA and SEEA for traded natural capital assets. However, there are significant data constraints, as the required information on operating and capital costs is rarely reported in publicly available datasets. Most of the estimates for this pilot account thus had to be based on research results and information from key contacts.

Resource rent estimates for most of the aquaculture systems included in this pilot account were positive and significant, including for salmon farms in Norway, tilapia farms in Egypt, shrimp farms in Ecuador and Indonesia, and a range of finfish species in Bangladesh. However, estimates for finfish aquaculture in Japan were more variable. A back-of-the-envelope extrapolation finds that the asset value of aquaculture could reach $1 trillion, which is significantly more than the value of marine capture fisheries currently included in CWON. To estimate the asset value of aquaculture for all major aquaculture-producing countries would require significant additional data collection and analysis. A key recommendation of this pilot study is to build a systematic and integrated data collection system consistent with SNA and SEEA methodologies and supported by an aquaculture economics community of practice comprising national statisticians, technical specialists, economists, and regulatory authorities. Data collection and analysis from 12 leading aquaculture-producing countries would be sufficient to cover 75 percent of the total value of global aquaculture production.

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9 Human Capital Wealth: Global Trends

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 60 percent of total wealth in 2020, slightly lower than in 1995.
- Significant disparity between male and female human capital persists across most regions and income groups, with great variation among regions: in 2020 women accounted for 44 percent of human capital in Latin America and the Caribbean, but only 15 percent in South Asia.
- Setting aside the impact that an influx of women in the labor market might generate, closing the gender gap could substantially improve human capital wealth. If gender parity were globally achieved, this could increase global human capital wealth by about 21 percentage points.
- Current CWON estimates are using a simple approximation for the changing educational composition of the work force. Future efforts should focus on improving the quality adjustments to the volume measures by compiling a global labor force that disaggregates workers by gender and educational levels.

INTRODUCTION

Human capital—the knowledge, skills, competencies, and attributes embodied in individuals that facilitate the creation of personal, social, and economic well-being—plays an increasingly central role in the economic success of nations and individuals (OECD 2001). Human capital is the main driver of sustainable growth and poverty reduction because more human capital is associated with higher earnings for individuals, higher income for countries, and stronger cohesion in societies (World Bank 2020).

Economic theory did not put enough emphasis on human capital before the 1950s, when economists started to consider human capital to account for income and growth differentials. In 1961, Theodore W. Schultz brought forward the idea of treating humans as a form of capital in his work called “Investment in Human Capital,” and developed the human capital theory of economic development. In 1962, Gary Becker developed the theoretical framework for human capital in his work called “Investment in Human Capital: A Theoretical Analysis.” In this work, he also introduced the economic concept of human capital and for the first time examined links between education and incomes. Since the 1980s, human capital has become one of the key components of the neoclassical growth accounting frameworks, as well as endogenous growth models. Today, human capital is accepted as the most important endowment of a country, making up about 60 percent of the total wealth of nations in 2020.

According to Gary Becker’s understanding, human capital is a broad concept. It includes not only education and training but also other additions to knowledge and health, such as accumulated work experience and health habits, even including harmful addictions, such as smoking and drug use (Becker 1962, 1993a, 1994b). Human capital wealth is essentially defined in this report as the present value of the future flow of wages and other labor earnings of the current working population, including both employed and self-employed workers. That is, it focuses on the economic benefits that a well-educated and healthy workforce generates.

CWON estimates human capital based on expected lifetime earnings. The first global estimates using expected lifetime earnings were produced for the 2018 edition of CWON, drawing on household surveys for 141 countries over two decades, from 1995 to 2014 (Lange, Wodon, and Carey 2018). This was a significant innovation to previous editions (World Bank 2006, 2011), which measured human capital indirectly as a component of the unexplained residual, called “intangible capital.”

This edition builds on the human capital methodology established in CWON 2018 by expanding coverage to 151 countries from 1995 to 2020 and introducing a volume-based index to estimate human capital in real terms.

The chapter is organized as follows. First, the estimation of human capital is summarized. The detailed methodology is included in CWON's methodology document (World Bank 2024). 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 and the importance of human capital in the informal sector.

ESTIMATING HUMAN CAPITAL

CWON 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 different approaches to measuring human capital (see Box 9.1 for more detail), 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.

BOX 9.1

DIFFERENT APPROACHES TO MEASURE 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 UN Development Programme's Human Development Index or the World Bank's HCI—combine multiple components to produce more comprehensive human capital indexes.

The *monetary measure-based 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). This is a useful method, but 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 consider 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 considers all the costs that are incurred when producing human capital. Therefore, the 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 account for demand and supply (Boarini, Mira d'Ercole, and Liu 2012). The income-based approach considers future earnings that human capital investment generates, and 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).

The lifetime income approach for measuring human capital stock brings together a broad range of factors that shape the stock of the working population. These factors include 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. All these factors are disaggregated by gender to capture both possible differences in access to education and healthcare, as well as the gender pay gap. The lifetime income is then computed for a representative male or female worker with a given educational background and experience. Real wages for future earnings for, say, a 30-year-old male worker when he is 50 are set equal to wages of male workers that are currently 50 with the same educational background.

An additional advantage of the lifetime income approach is that it allows changes in human capital to be described in terms of investment and stocks. 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).

However, because this approach builds on the concepts and measurement of market labor earnings in the SNA, CWON human capital estimates have a major omission: human capital that produces nonmarket 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.[203] As a result, the human capital associated with the production of household services is not measured—an omission that disproportionately affects the measure of women's human capital.

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 (see Box 9.2 for more detail). While these indicators are computed for the entire population, CWON's measures of human capital focus only on the current working population. Moreover, this approach emphasizes the role of human capital in generating income through wages and earnings, but does not recognize other essential benefits from investments in human development, such as the intrinsic value of a good education and good health. However, for wealth accounting purposes, the focus needs to remain strictly on the monetary estimates of wealth associated with human capital. Therefore, human capital estimates in CWON are an underestimate because they leave out positive externalities, such as the public good benefits of an educated population, and restrict the measure to the current working population not the total population.

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[203] Note that regularly accounting for households' unpaid service work is a recommended extension in the new SNA 2025, which would be compiled and released periodically. However, it will not be part of standard measures. For more information on the 2025 revision of the SNA see: https://unstats.un.org/unsd/nationalaccount/towards2025.

BOX 9.2
THE HUMAN CAPITAL INDEX AND CWON'S HUMAN CAPITAL

The World Bank's HCI is an international metric measuring the human capital that a child born today can expect to attain by their 18th birthday, given the risks of poor health and poor education prevailing in their 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 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. 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 CWON estimates expected future earnings of the current labor force*. In addition, CWON reports estimates in monetary terms, while 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 they would be if they enjoyed complete education and full health.

The CWON measure of human capital complements the HCI, using outcomes that derive indirectly from factors such as educational attainment and health to provide an understanding of the current stock of human capital in countries. CWON also 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 introduced the utilization-adjusted index. This analytical extension accounts for the underuse of human capital, based on the fraction of the working age population that is employed, or in the types of jobs that might better enable them to use their skills and abilities to increase their productivity.

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

DATA SOURCES AND METHODS

To compute human capital as the discounted value of expected future labor income, data on the population, employment, annual earnings, survival rates, GDP, and labor shares are needed from different data sources. The International Income Distribution Database, a unique database developed by the World Bank containing more than 1,500 harmonized household surveys, is used for calculating annual earnings, educational attainment, and employment rates. The survey information from the World Bank's International Income Distribution Database[204] was complemented in this update with harmonized labor force surveys from the World Bank's Global Labor Database,[205] the Luxembourg Income Study,[206] and the New Zealand Treasury. Thus, the country coverage for this edition of CWON increased to 151 countries, by adding Angola, Guinea-Bissau, Israel, New Zealand, and St. Lucia.

The consolidated database of household and labor force surveys is used to estimate the private returns per year of schooling. This requires collecting data from the harmonized surveys on the number of people, their earnings, school enrollment rates, and employment rates, and then to estimate the Mincerian coefficients using the Mincerian wage regressions. Based on these results, a matrix of expected earnings is constructed, which accounts for labor earnings of the population by age, gender, and education level.

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 15 are assumed to be in school. Individuals between the ages of 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 NPV, a uniform discount rate of 4 percent is used for human capital to ensure consistency across assets.

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[207] are used. The shares of compensation of employees and the self-employed in the national accounts are retrieved from the PWT 9.1 to control the estimated wages. Finally, employment data from the ILO are used for controlling and scaling up total employment from the consolidated database. The data and methods are described further in CWON's methodology document (World Bank 2024).

Because the survey data do not capture the entire world population, the data from the surveys are adjusted to population estimates from the UN's World Population Prospects[208] to ensure that the estimates are representative. In addition, the earnings profiles are not compatible with the published data from the SNA because the 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 PWT. Expected labor earnings from the surveys are scaled up to the labor earnings in the UN's National Accounts database. In addition, no adjustments are made for the future wage forecasts in line with the international guidance (SNA/SEEA), which calls for resource rents to be held constant in the NPV calculation. In other words, no future wage growth is assumed for all countries.

Using this in-formation, the lifetime income (adjusted by survival rates and a discount factor) can be calculated for the representative individual (aged 15–65) by age, gender, and education. Subsequently, these lifetime income profiles are multiplied by the corresponding number of people in a country to compute the human capital stock by age, gender, and education. Summing the stocks of human capital across all classified categories generates an estimate of the aggregate value of the human capital stock for each country.

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[204] 1,147 surveys were used from the I2D2 database.
[205] 52 surveys were used from the Global Labor Database (https://worldbank.github.io/gld/).
[206] 382 surveys were used from the Luxembourg Income Study (https://www.lisdatacenter.org/).
[207] https://www.healthdata.org/research-analysis/gbd.
[208] https://population.un.org/wpp/.

To compute human capital in real terms, quality-adjusted labor force data disaggregated by gender are used as a "volume" measure. The labor force data are taken from the ILO and adjusted for the changing educational composition of the labor force or "quality" by multiplying these volumes by the HCI from the PWT.[209] This allows us to approximate the average human capital per worker. This is a simple adjustment for the quality changes in the labor force over time, since the HCI assumes constant, global Mincerian coefficients and does not account for the quality of education. Ideally, the labor force data should have more detail, disaggregating workers by their gender, years of education, and experience. Experimental estimates for a subset of countries for which such data exist suggest that this is a reasonable first approximation (for more detail see Box 9.3). Future efforts should focus on building the necessary detail in the labor force data to use as improved volume measures.

GLOBAL TRENDS IN HUMAN CAPITAL WEALTH

This section presents the estimates of human capital across countries and trends in human capital over the 1995–2020 period. 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 60 percent of total wealth at the global level, dropping from 61 percent in 1995 to 60 percent in 2020 (Table 9.1). 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 upper-middle-income and high-income countries in 2020, but only about 50 percent in low-income and lower-middle-income countries.

Trends in human capital differ over time between different income groups. On average, the share of human capital in high-income countries (including both OECD and non-OECD countries) plateaued during 1995–2020, while it substantially 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 due to aging. But, in many middle- and low-income countries, educational attainment and returns to education are still growing, and human capital is rapidly increasing.

TABLE 9.1

Human capital as a share of total wealth, 1995–2020

	1995	2000	2005	2010	2015	2020
World	**61.2**	**60.8**	**57.5**	**58.7**	**62.7**	**60.2**
Low income	30.2	38.9	37.1	37.5	44.5	49.7
Lower middle income	44.3	47.0	47.1	52.4	56.1	54.3
Upper middle income	52.8	56.5	53.6	58.6	65.7	60.9
High income: OECD	63.3	62.0	58.8	59.3	62.4	60.5
High income: Non-OECD	60.8	60.0	55.8	59.6	63.8	64.9

Source: World Bank staff estimates.

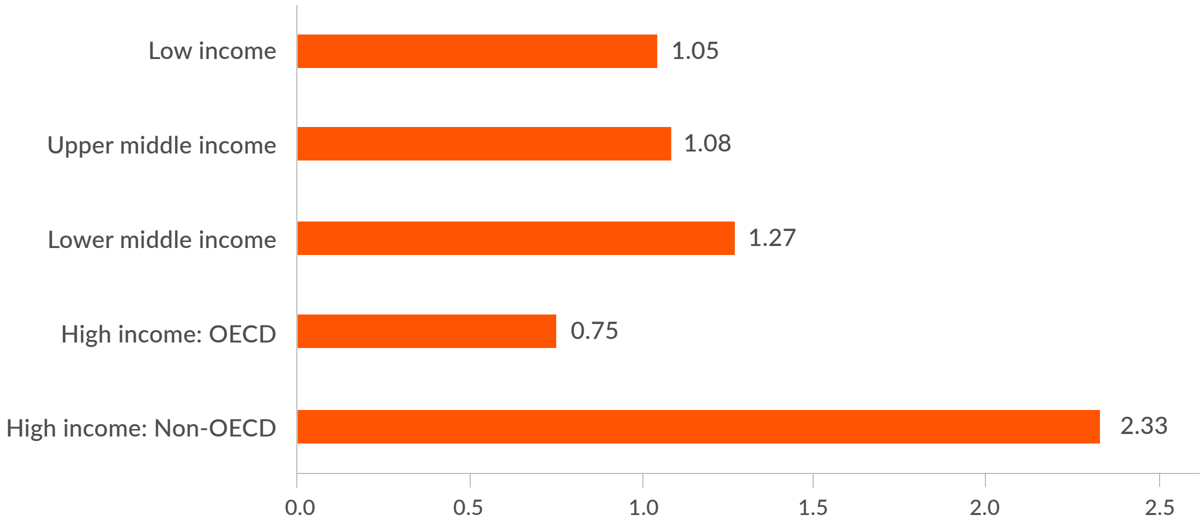
Note: Shares are computed using human capital wealth measured in current US dollars and are reported as percent. OECD = Organisation for Economic Co-operation and Development.

Inequality in total wealth across income groups extends to human capital as well. Real human capital per capita in high-income OECD countries in 2020 was about 65 times that in low-income countries, and about 32 times that in lower-middle-income countries. In high-income OECD countries, human capital per capita was close to $331,418 (in chained 2019 US dollars), while it was only $5,215 in low-income countries. This significant disparity between low- and high-income countries reflects the difference in incomes.

Human capital per capita in real terms tends to grow faster as countries' income increases (Figure 9.1). High-income non-OECD countries experience the highest growth rate at 2.33 percent, followed by lower- and upper-middle-income countries (1.27 percent and 1.08 percent, respectively) and low-income countries (1.05 percent). The main exception is high-income OECD countries, which experience considerably lower growth rates at only 0.75 percent due to stagnating wages and aging populations.

FIGURE 9.1

Annual growth rates of human capital per capita, 1995–2020



Source: World Bank staff estimates.

Note: Human capital wealth is measured in chained 2019 US dollars. OECD = Organisation for Economic Co-operation and Development.

REGIONAL TRENDS IN HUMAN CAPITAL

Ranging from about half to two-thirds of total wealth, human capital makes up the largest share of total nominal wealth in all regions. While human capital's share is about half in Sub-Saharan Africa and the Middle East and North Africa regions, human capital constitutes 65 percent of Latin America's wealth and 63 percent of Europe and Central Asia's wealth (Table 9.2). Human capital's share in total wealth is between 55 percent and 60 percent in other regions. In addition, the share of human capital in total nominal wealth increased from 1995 to 2020 in most regions. For example, South Asia and Sub-Saharan Africa experienced notable growth in the proportion of human capital within total wealth. In 1995, this share stood at approximately 48 percent for South Asia and 44 percent for Sub-Saharan Africa, and rose to 56 percent and 50 percent, respectively, by 2020. In contrast, the share of human capital in total wealth dropped substantially in North America (by 7 percentage points) and to a lesser extent in East Asia and the Pacific (by 3 percentage points).

TABLE 9.2

Human capital as a share of total wealth, by region, 1995–2020

	1995	2000	2005	2010	2015	2020
East Asia and the Pacific	59.3	56.2	53.9	54.8	59.6	56.5
Europe and Central Asia	58.0	56.4	54.9	59.1	64.6	62.8
Latin America and the Caribbean	62.1	62.5	61.9	69.1	71.8	65.4
Middle East and North Africa	52.3	51.5	44.3	48.5	57.1	54.8
North America	68.9	69.0	63.8	61.2	63.5	62.0
South Asia	48.0	54.4	55.9	55.5	60.0	56.2
Sub-Saharan Africa	44.4	39.1	40.4	50.6	50.2	50.1

Source: World Bank staff estimates.

Note: Shares are computed using human capital wealth measured in current US dollars and are reported as percent.

Human capital per capita in real terms has grown consistently for the past 25 years due to increasing labor force participation and higher returns to education. The world's real human capital per capita increased by 9 percent between 1995 and 2020, but there are contrasting trends across regions (Figure 9.2).[210] Human capital is concentrated in the high- and upper-middle-income countries of North America (34 percent of the global value of human capital), Europe and Central Asia (27 percent), and East Asia and the Pacific (27 percent), as shown in Figure 9.3. These regions have experienced modest growth rates, with 12 percent in North America and 16 percent in East Asia and the Pacific. In contrast, the Middle East and North Africa, and Latin America and the Caribbean regions show much larger increases of 82 percent and 62 percent, respectively, over the same period—albeit from a much lower starting point (their shares in the nominal value of human capital are 2 percent and 5 percent, respectively).

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[210] The growth rate in global human capital per capita is so low, since there have been small increases in the share of global human capital in South Asia (from 2.6 percent in 1995 to 3.2 percent in 2020) and Sub-Saharan Africa (from 1.1 percent to 1.8 percent). While these changes are small in absolute terms, they are able to depress the global growth rate in human capital per capita due to significant differences in value of human capital relative to richer regions. For example, North America has a nominal value of human capital that is 60 times higher than in South Asia and Sub-Saharan Africa.

FIGURE 9.2

Human capital per capita, by region, 1995–2020 (1995=100)

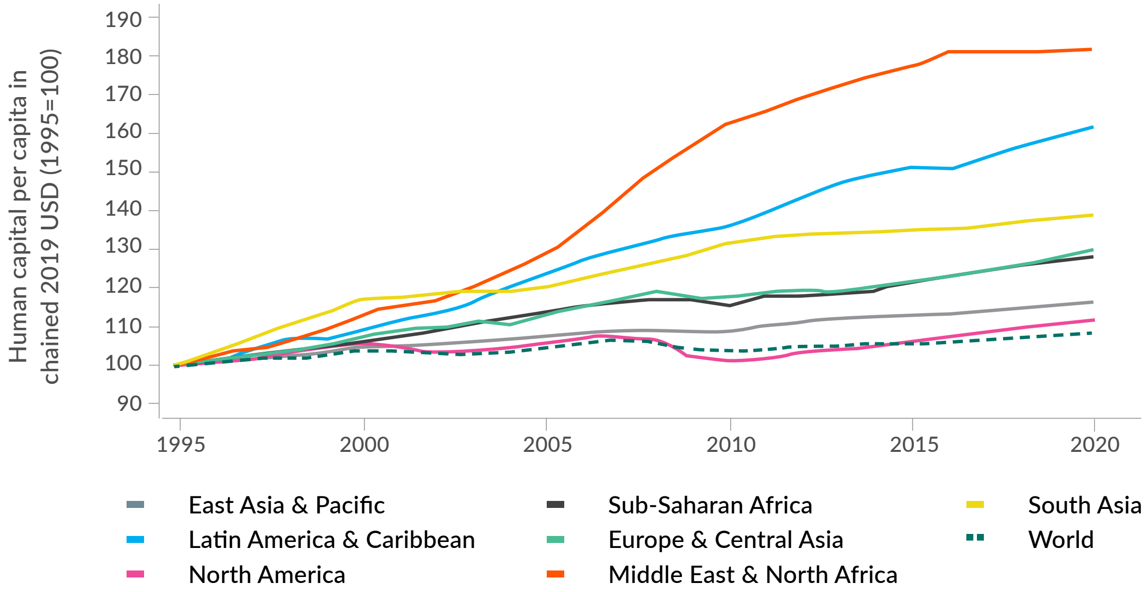
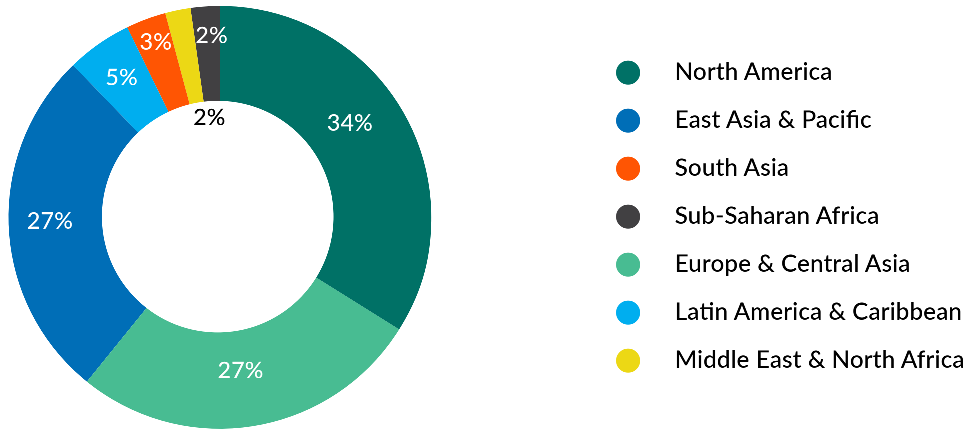


FIGURE 9.3

Nominal shares of human capital, by region, 2020



Source: World Bank staff estimates.

Note: Real human capital per capita is measured in chained 2019 US dollars. Shares in nominal wealth are measured in current US dollars.

GENDER AND HUMAN CAPITAL

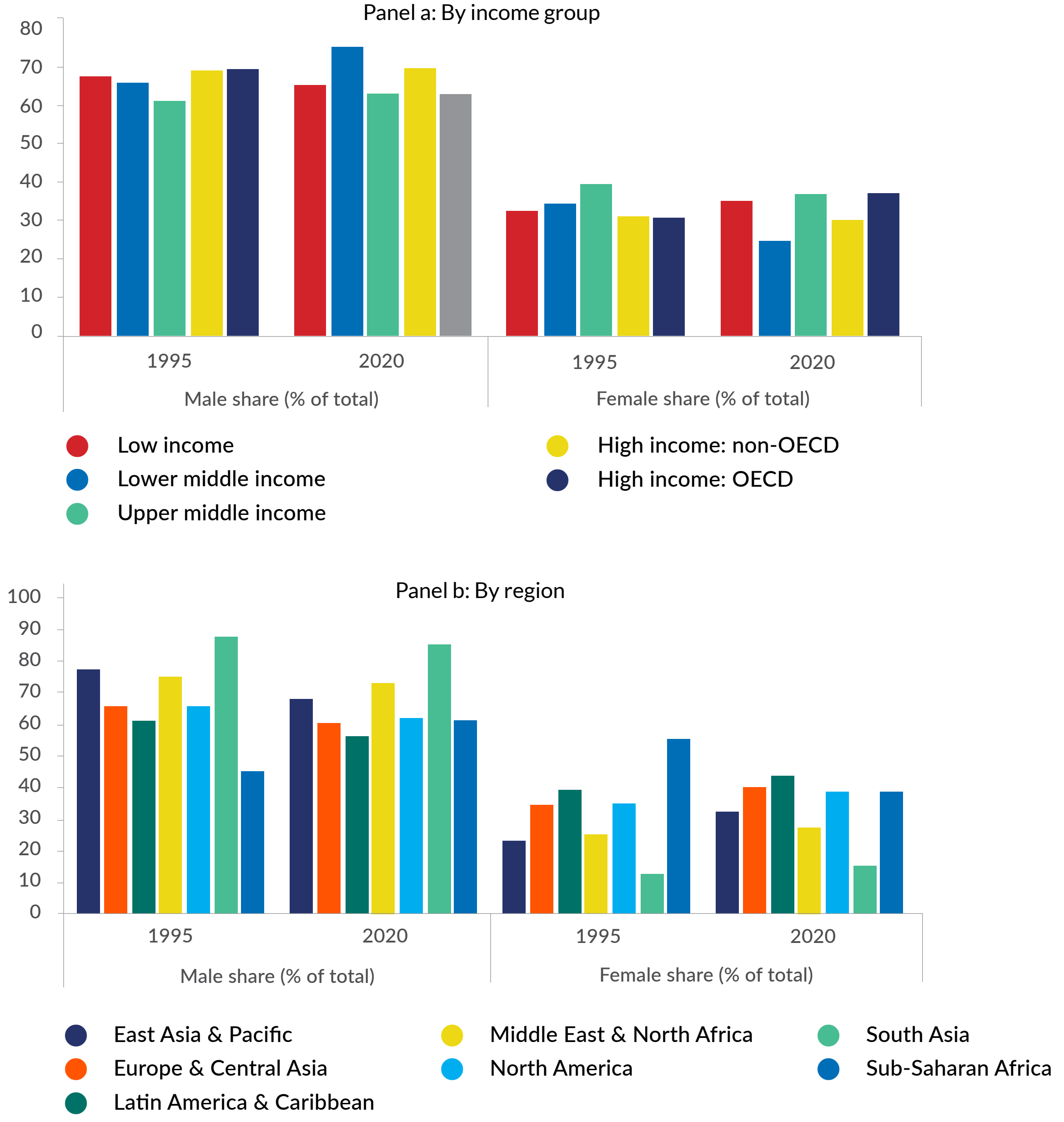
Since human capital wealth is estimated using the current wage, education, and experience profiles for a stock of human capital, the productivity differences between men and women are captured by the Mincerian parameters. In addition, the extent to which the non-monetary aspects of human capital impact wages, education, and work experience, such as the health and skills of workers as well as their access to economic opportunities and education, are captured in the estimated Mincerian coefficients. Therefore, a difference in human capital across gender and a gender gap indicates the disparity between men and women in terms of both monetary and non-monetary aspects of human capital. Unfortunately, the human capital estimates reveal a significant disparity between the male and female shares of human capital. Moreover, little progress has been made toward greater gender parity in human capital over 1995–2020.

Although higher levels of economic development are generally associated with a higher share of women in human capital, women accounted for just 36 percent of human capital in 2020 (measured in nominal terms), which was only 4 percentage points greater than in 1995.

While women account for a quarter of human capital wealth in lower-middle-income countries, they make up less than one-third of human capital in high-income non-OECD countries and about one-third of low-income countries' human capital wealth. The share of women is slightly greater than one-third of human capital in upper-middle-income and high-income OECD countries, compromising about 37 percent of human capital wealth.

FIGURE 9.4

Shares of human capital by gender, 1995–2020



Source: World Bank staff estimates.
Note: Shares are computed using human capital wealth measured in current US dollars. OECD = Organisation for Economic Co-operation and Development.

The differences between regions are even more striking. As shown in Figure 9.4, women accounted for only 15 percent of human capital in South Asia in 2020, 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's human capital wealth was 40 percent and slightly below 40 percent in North America and Sub-Saharan Africa. Women account for less than one-third of human capital wealth in East Asia and the Pacific, and the Middle East and North Africa.

These results indicate 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. There are several other factors causing the gender disparity in human capital, including:

- Careers that are interrupted for childbearing.
- Penalties for childcare, as women work part-time to meet family needs and as employers question the commitment of women to their career.
- 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.
- Barriers that prevent women from attaining similar economic opportunities as men.
- A lack of women in leadership positions in the workforce.

Gender discrimination fosters and reinforces many of these negative influences on women's earnings (World Bank 2023; Georgieva, Sayeh, and Sahay 2022).

To capture the magnitude of gender-based disparities in human capital over time, Table 9.3 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 2020, the global gender gap in human capital was 57 percent, meaning that the remaining gap to close is 43 percent. Although there was progress from 1995 to 2020, global progress was not satisfactory: only 10 percentage points. In 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 1995–2020, narrowing the gap by 14 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 of 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 18 percent in South Asia to 78 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 (World Bank 2023). 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 two-thirds.

TABLE 9.3

Potential gains in human capital from gender equity, 1995–2020

	Gender gap ratio (x100) (ratio of human capital wealth by gender)						Potential gain from gender equity (percentage increase from base)					
	1995	2000	2005	2010	2015	2020	1995	2000	2005	2010	2015	2020
World	47	48	53	56	56	57	27	26	24	22	22	21
INCOME GROUP												
Low income	48	50	51	51	52	54	26	25	24	24	24	23
Lower middle income	52	36	32	32	34	33	24	32	34	34	33	34
Upper middle income	65	69	64	64	60	58	18	16	18	18	20	21
High income: Non-OECD	45	44	43	41	41	43	28	28	28	29	30	28
High income: OECD	45	46	52	56	57	59	28	27	24	22	21	20
REGION												
East Asia and the Pacific	30	32	35	42	47	47	35	34	33	29	26	26
Europe and Central Asia	52	53	59	62	63	65	24	23	20	19	18	17
Latin America and the Caribbean	64	72	72	77	76	78	18	14	14	12	12	11
Middle East and North Africa	34	34	33	32	35	37	33	33	34	34	33	31
North America	53	54	58	64	60	63	23	23	21	18	20	19
South Asia	15	14	16	17	17	18	43	43	42	42	42	41
Sub-Saharan Africa	123	93	65	52	65	63	-12	3	17	24	18	18

Source: World Bank staff estimates.

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

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 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) × 50/100. As shown in Table 9.3, 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 substantial. 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 about 41 percentage points (Table 9.3). These simple simulations do not account for the general equilibrium impact that an influx of women in 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.

CONCLUSIONS

This chapter provided a set of comparable estimates of human capital based on a time series of household surveys for 151 countries throughout 1995–2020. Human capital accounts for about 60 percent of total global wealth. 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 slightly above one-third, and progress in closing the gender gap has been slow over the 1995–2020 period.

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—this requires direct investment, such as education, but it also requires broader investment in a healthy environment, water, sanitation, and clean air.

In future work, the methodology could be further improved, most notably the volume measures used in the estimation of human capital in real terms. The weights in the current methodology are already incorporating productivity improvements that are reflected in higher nominal values of human capital. However, the volume measures are currently adjusted with a simple correction factor that is not able to approximate the changing educational composition of the labor force in more detail. More detailed labor force data are necessary, but global coverage of such data is currently limited. Experimental estimates for a subset of countries are presented in Box 9.3, which illustrates that, while the simple adjustment is an important first step, more insights can be gained from using more detailed labor force data.

BOX 9.3
EXPERIMENTAL ESTIMATION OF QUALITY-ADJUSTED HUMAN CAPITAL

This edition of CWON estimates the value of human capital using the number of people aged 15–65 and their lifetime income profiles based on age, being male or female, and education (as detailed in chapter 2). For the computation of the real human capital estimates in chained 2019 US dollars, the quantity relatives are derived from the number of male and female workforce reported by the ILO's Department of Statistics adjusted for by the HCI of the PWT.[211] This adjustment proxies for the changing educational composition of the labor force or its "quality" by approximating average human capital per worker. However, the HCI is a simple adjustment, as it does not allow Mincerian coefficients to differ across countries and by gender. It also does not account for the quality of education, by simply using years of education in the construction of the HCI, which provides an overestimate of educational attainment, particularly in low-income countries where the quality of education is low.[212]

To better reflect increased education attainment of the labor force, future editions of CWON could collect detailed labor force data disaggregated by gender and education levels. The advantage of such an approach is that it would directly account for changes in the composition of the workforce and would assign differential weights to each worker based on their educational attainment (with larger weights attributed to higher levels of education as determined by the nominal human capital wealth estimates). For example, if the share of higher-educated workers in the labor force increases over time, the Törnqvist volume index would assign a greater weight to these workers, reflecting their higher level of nominal human capital. This is indeed the approach chosen by the statistical offices of Canada[213] and the UK,[214] which are the only countries publishing experimental human capital estimates. Unfortunately, there is currently no global database available to provide labor force data disaggregated by gender and education level for all the countries in the CWON database.

However, some countries have a complete ILO labor data series. To illustrate how this sophisticated quality adjustment compares to the current estimates, experimental estimates of human capital in real terms were produced for Indonesia and the United States using ILO working age male and female populations disaggregated into four aggregated education levels—lower than basic, basic, intermediate, and advanced quality. These data are used to compute the quantity relatives for eight human capital components (male with lower than basic education, female with basic education, and so on) that are inserted into the Törnqvist volume index formula to compute human capital in real terms.

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[211] https://www.rug.nl/ggdc/productivity/pwt/?lang=en.

[212] The value of human capital in low-income countries is constrained by a lack of produced capital broadening and deepening (the low-income trap) and while they have experienced increases in years of education this translates into modest gains in human capital due to low-quality education and low returns to education. In fact, while years of education have increased in these countries, learning poverty (children under 10 who cannot read) has risen as well.

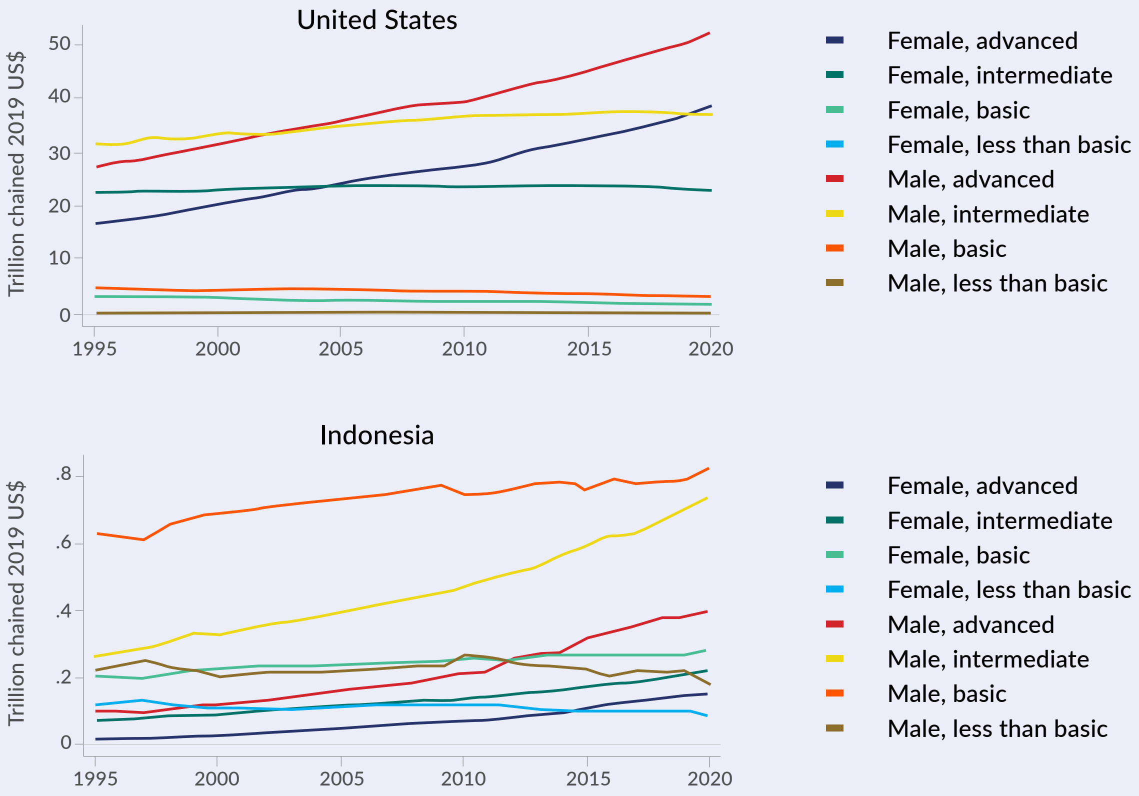
[213] https://www150.statcan.gc.ca/n1/en/catalogue/11F0027M2010062.

[214] https://www.ons.gov.uk/peoplepopulationandcommunity/wellbeing/datasets/humancapitalestimatessupplementarytables.

Indonesia and the United States were chosen because they have a similar size of population and labor force, but with a different composition in education attainment. In 2022, the US population with basic education earned 1.25 times more than people with lower than basic education. The population with intermediate and advanced education earned on average 1.4 and 2.6 times, respectively, more than the population with lower than basic education. Indonesia had similar earnings ratios for its different education levels, and these levels are matched with ILO aggregate education definitions. Following the Törnqvist volume index formula, the total human capital nominal value is divided into each education group and weighted by average earnings ratios.

The United States, which has a larger and increasing share of population with advanced education levels compared to Indonesia (Figure 9.3.1), has a higher growth rate in real human capital per capita when the more detailed labor force data are used (Figure 9.3.2). On the other hand, for Indonesia, which has a larger and growing share of a working age male population with intermediate and basic education, the human capital growth is revised downwards when using the more detailed labor force data, since it capture more directly the lower returns to education by these types of workers.

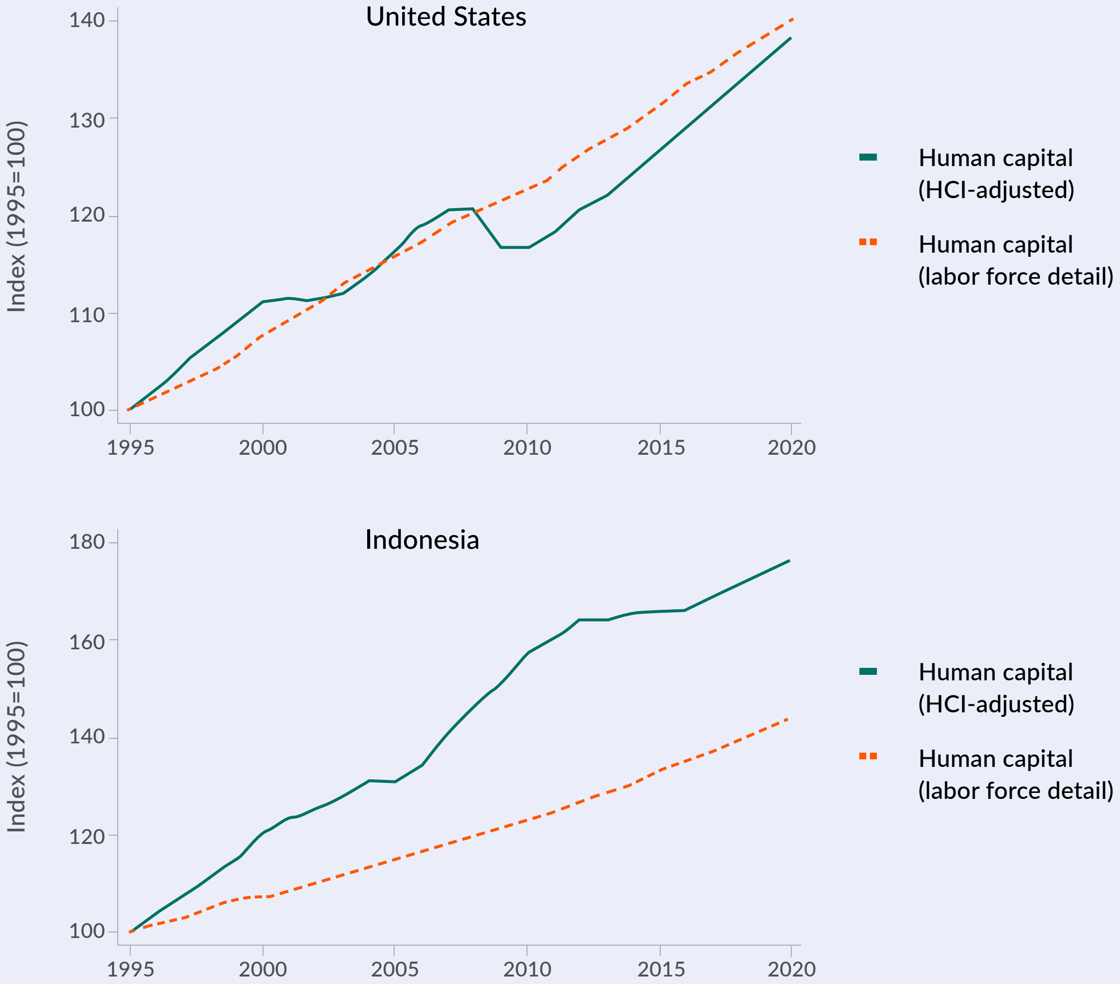
BOX FIGURE 9.3.1
Real human capital by education level



Source: World Bank staff estimates.
Note: Human capital wealth is measured in chained 2019 US dollars. These estimates are based on data from ILO, BLS and BPS.

BOX FIGURE 9.3.2

Real human capital vs. quality-adjusted real human capital, indexed



Source: World Bank staff estimates.
Note: Human capital wealth is measured in chained 2019 US dollars.

These results suggest that more nuanced insights into trends in human capital can be gained from using more detailed labor force data. However, further research is needed to develop a global labor force database with the necessary detail.

There is scope to further improve the computation of the human capital estimates, including increasing the number of surveys used and improving the gap-filling approach between surveys. Further research and analysis on the factors driving the large differences between men 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.

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Conclusions

MAIN MESSAGES

- Real comprehensive wealth per capita estimates provide an important indicator of sustainable development. However, most countries do not produce the necessary underlying data to develop country-level real wealth estimates.
- To fill this data gap, the World Bank's CWON program produces comparable and consistent estimates of real comprehensive wealth per capita for more than 150 countries for the 1995–2020 period. These estimates are aligned with internationally accepted statistical standards and guidelines and are complementary to headline indicators, such as GDP.
- To transition the CWON program into a regular statistical program, several conceptual and practical challenges remain. These range from decisions around the appropriate discount rate and lifetime of renewable natural capital resources, to improved measurement of the quality of volume measures, prices, and selected assets.

A NEW HEADLINE INDICATOR FOR SUSTAINABILITY: CHANGES IN REAL WEALTH PER CAPITA

Decision-makers are increasingly placing sustainability and the enhancement of well-being at the center of policy discourse. This includes national and international policy dialogues around the SDGs,[215] the beyond GDP agenda,[216] and the importance of mainstreaming nature into decision-making processes. To help steer these dialogues and policy decisions, evidence and data are needed, especially a headline indicator that can help assess aggregate progress toward the SDGs and sustainability more broadly.

Whether progress is sustainable—that is, whether future generations will have at least the same production and consumption opportunities as the current generation—can be assessed with changes in real wealth per capita, measured comprehensively to include produced, human, and natural capital, as well as net foreign assets. Changes in real wealth per capita capture how future production and, ultimately, consumption opportunities of a country change over time. They provide key insights into the sustainability of current development patterns—as measured by changes in real wealth per capita and its components—and the policy environment driving them. Constant or increasing real wealth per capita is thus an important indicator of sustainability.

A key challenge in developing real wealth per capita estimates is that, even when the necessary data are collected, they are not organized in a way that facilitates reporting by national statistical offices on comprehensive wealth. For example, the physical measures and economic data necessary for valuation are not easily integrated. Organizing data, building data-sharing mechanisms, and providing administrative support are challenges in many countries. In other cases, the necessary data are simply not collected. This is especially the case in countries with low statistical capacity. While there have been growing calls for better accounting for the environment and natural capital in macroeconomic statistics, including from the UN Secretary General,[217] the G7[218] and G20,[219] and leading academics,[220] implementation is lagging. Though more than 90 national statistical offices develop natural capital or ecosystem

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[215] https://sdgs.un.org/goals.

[216] https://unsceb.org/topics/beyond-gdp.

[217] https://unsceb.org/valuing-what-counts-united-nations-system-wide-contribution-beyond-gross-domestic-product-gdp.

[218] This includes by the G7 Communique of 2018 (https://www.international.gc.ca/world-monde/assets/pdfs/international_relations-relations_internationales/g7/2018-06-09-summit-communique-sommet-en.pdf), the Environment Ministers' Communiques of 2022 (https://www.bundesregierung.de/resource/blob/974430/2044350/84e380088170c69e6b6ad45dbd133ef8/2022-05-27-1-climate-ministers-communique-data.pdf?download=1) and 2023 (https://www.meti.go.jp/press/2023/04/20230417004/20230417004-1.pdf), and the G7 Science Ministers' Communique in 2023 (https://www8.cao.go.jp/cstp/kokusaiteki/g7_2023/230513_g7_communique.pdf).

[219] This includes the G20 Data Gaps Initiative of the International Monetary Fund (https://www.imf.org/en/News/Seminars/Conferences/g20-data-gaps-initiative), which has identified several climate change indicators and national accounts distributions as critical data gaps for policy.

[220] For example, Arrow et al. (2004), Fleurbaey (2009), Guerry et al. (2015), Jorgenson (2018), and Hulten and Nakamura (2022).

accounts (UN 2023), their coverage is often limited, even for OECD countries (see chapter 1). Practically no country measures human capital.

The World Bank's CWON program aims to fill this data gap. The CWON database offers the most comprehensive and consistent wealth estimates currently available, and these estimates are comparable with and complementary to other headline macroeconomic indicators, such as GDP. The current update of the CWON database implements an important methodological innovation that affects how real comprehensive wealth is measured. With this edition, a Törnqvist volume index is used to compute real comprehensive wealth estimates. Changes in real comprehensive wealth per capita measured in this way signal whether the productive base of an economy (that is, its assets) is growing or shrinking over time due to changes in the quantity—or volume—of assets available. It also reflects how the scarcity and productivity of different assets change relative to others (through relative price changes) as time goes by. This shift to a volume-based index is in line with international statistical guidance and is a significant improvement relative to previous editions of CWON, which used the GDP implicit price index for deflation. However, there remain several methodological and practical challenges to be addressed before the CWON program can mature into a statistical program producing regular and consistent updates of real wealth measures.

THE WAY FORWARD FOR THE CWON PROGRAM

As done in previous editions, the current CWON release has expanded the asset boundary, adding assets for which data sources and methodological approaches are available. To mature to a regular statistical program, the CWON program would need to be more systematic, defining measurement boundaries conceptually rather than pragmatically. These boundaries should match those in the SNA and SEEA as closely as possible, with selected extensions as required to permit the assessment of sustainability (for example, for human capital). This would enable the CWON program to maintain alignment with the SNA and SEEA, while recognizing that those guidebooks reflect what is internationally agreed as a statistical standard and not necessarily what is needed to fully assess sustainability. It would also allow the program to report summary changes in wealth aligned with each boundary along with a single summary (see, for example, OSTP, OMB, and DOC 2023).

The question of what set of assets is appropriately included within the CWON measurement boundary remains an area of active discussion. Future wealth assessments must resolve this to stabilize the asset boundary and focus the work on updating the database rather than expanding it. This will enhance the usability and comparability of the data across editions. Of course, there will remain a need to occasionally expand the asset boundary, as understanding of the assets that contribute to well-being deepens and as the economy, society, and environment evolve. Such expansions will, however, be undertaken occasionally rather than continually and in a way that maintains maximum comparability of the database across time and countries.[221]

In addition, several methodological and measurement concerns remain that need to be addressed—drawing on the latest research, international guidance, and implementation experience—to further improve the real comprehensive wealth per capita estimates. Regarding methodology, more work is needed to determine the appropriate discount rate for CWON to address concerns around the limited substitutability of assets and intergenerational equity in access to wealth. In addition, the assumption of a 100-year lifetime for renewable natural resources requires revisiting given the evidence that climate change is affecting the environment and the economy more quickly and seriously than anticipated. There are also several measurement challenges to be addressed, including (i) adjusting asset volumes in the Törnqvist index to reflect not just changes in quantities but also in quality; (ii) producing real estimates of wealth and its components in purchasing parity power terms; (iii) improving measurement of urban land, timber, renewable energy, aquaculture, and water assets; (iv) improving spatial integration and delineation of the contribution of protected areas for land assets; and (v) collecting subsidy data for all assets.

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[221] For all editions of CWON so far including this update, it is not possible to compare databases given that both methods and asset coverage have changed across editions.

THE USES OF THE CWON DATABASE

CWON data are already being used widely by World Bank task teams, the academic community,[222] the private sector,[223] and other multilateral actors. The main use of the CWON data is to conduct sustainability analyses by comparing the trends in real comprehensive wealth per capita and its components over time and across countries. As shown in this report, both trends in real comprehensive wealth per capita and its components can provide key insights into the sustainability of current development patterns, as well as into the evolution of the underlying asset portfolio. This analysis can reveal which assets are being degraded too fast relative to population growth and which sectors require targeted investment to continue building aggregate real wealth per capita. Since the CWON database primarily draws on global data sources, it is best suited for analysis of trends both within and across countries. It lacks the necessary granularity to inform the design of specific interventions at the subnational scale.

With this new release of CWON data, it is possible, for the first time, to construct customized country-level wealth estimates. Previous editions of CWON only made available the final nominal and real wealth estimates for comprehensive wealth and its components. As part of the World Bank's reproducibility initiative, the entire statistical code used to generate the estimates will be publicly released on the World Bank's website together with the detailed input data. The only exception is licensed datasets for which dummy datasets will be provided. This unprecedented access will provide users with the opportunity to build on the CWON database and code to customize wealth estimates for specific countries. This may involve using more granular, country-level input data and modifying the assumptions used to estimate the nominal and real wealth estimates. Several examples of country-level wealth estimates using a similar methodology to CWON have recently been produced (see Box 10.1), showing the feasibility of such country-level exercises.

The opening up of the CWON input data and code will also facilitate policy and scenario modelling by allowing users to decide for themselves how to treat key aspects of the methodology. For example, in line with standard statistical practice, the CWON database provides conservative baseline estimates of wealth that hold future rents constant. This means the estimates reflect the current policy environment and market expectations and are blind to the possible effects of future policy actions or changes in market conditions due to, for example, climate change. To explore "what if" scenarios, researchers will now be able to adapt the CWON input data and code to change this assumption—and any other aspect of the methodology they wish—in modelling exercises to derive their own, policy-contingent, wealth estimates. Several examples of such analysis are under way within the World Bank using computable general equilibrium models. Many similar analyses and modelling frameworks are available that users can explore to answer their unique policy questions using the latest release of the CWON database.

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[222] A recent example includes an analysis of the unequal climate impacts on global values of natural capital by Bastien-Olvera et al. (2023). The Institute for Global Sustainability at Boston University also frequently draws on the nonrenewable natural capital data as part of its Visualizing Energy project (https://visualizingenergy.org/).

[223] One key example is the Sovereign Environmental, Social, and Governance data portal of the International Finance Cooperation (https://esgdata.worldbank.org/?lang=en), which curates a wide range of data for policy makers, financial market participants, and academic researchers. This database includes CWON data as one of its primary sources of natural capital data.

BOX 10.1
IMPLEMENTATION EXPERIENCE FROM COUNTRY-LEVEL WEALTH ESTIMATES

The International Institute for Sustainable Development (IISD) has played a leading role in promoting the measurement of comprehensive wealth for nearly a decade. Its efforts began with two reports on comprehensive wealth for Canada (IISD 2016, 2018). These reports painted quite a different picture of Canada's development than that offered by GDP alone. While Canada did well with GDP as the gauge of success, comprehensive wealth analysis showed that success to rest on a shaky foundation. According to the IISD's figures,[224] human capital—Canada's greatest asset[225]—was stagnant in per capita terms from 1980 to 2015. At the same time, natural capital was declining, produced capital was overly concentrated in fossil fuel extraction and residential housing, and financial capital was too reliant on holding gains on foreign assets.

Building on what it learned from the two Canadian studies, the IISD next tackled the more complex challenge of measuring comprehensive wealth in countries with less advanced statistical systems. With funding from the Canadian International Research Development Centre, the IISD worked from 2020 to 2024 with researchers and experts in Ethiopia, Indonesia, and Trinidad and Tobago to compile comprehensive wealth estimates for those countries. A primary motivation for the project was to determine if comprehensive wealth estimates could be compiled in countries with limited statistical resources using mainly nationally sourced data, following methods and time frames like those used in CWON.[226]

Although the results of the project remain to be published, three findings are clear. First, it proved possible to compile comprehensive wealth figures for the study countries using data available from national sources (mainly the national statistical offices and central banks). This suggests that comprehensive wealth accounts, while by no means straightforward to compile, should be feasible in almost any country. Second, while the IISD's results are not identical to those in CWON, there is generally good agreement between them. This suggests that CWON's global methodology yields credible results for individual countries. Finally, as in Canada, comprehensive wealth analysis reveals features of development in the three countries that are not apparent from GDP data alone: decline of natural capital, highly concentrated produced capital, and lack of investment in human capital. This suggests that comprehensive wealth accounting is worth the effort, as it provides a missing—and urgently needed—perspective on national progress that GDP cannot.

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[224] The IISD drew the figures for its analysis directly from Statistics Canada, Canada's national statistical agency, so the results are considered to be as robust as possible given current concepts, methods, and data.

[225] Human capital is not just Canada's greatest asset, but the most important asset in every country.

[226] The main exception is the method the IISD used to value human capital, which was a simplified approach based on national accounts labor compensation data. This choice was made not because the lifetime income approach used in CWON was deemed impracticable, but because project resources did not support its application (it is analytically intensive).

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