MPRA
Munich Personal RePEc Archive

Tracing the Evolution of Natural Capital in Global Sustainability Metrics: The Advance of Inclusive Wealth

chen, shuning and Managi, Shunsuke

Urban Institute, Kyushu University

5 November 2024

Online at https://mpra.ub.uni-muenchen.de/122597/
MPRA Paper No. 122597, posted 19 Nov 2024 22:44 UTC

Tracing the Evolution of Natural Capital in Global Sustainability Metrics: The Advance of Inclusive Wealth

***Shuning CHEN**

Email: chen.shunign.306@m.kyushu-u.ac.jp

Urban Institute, School of Engineering, Kyushu University, 744 Motooka Nishi-Ku Fukuoka, Japan

Shunsuke Managi

Email: managi@doc.kyushu-u.ac.jp

Urban Institute, Kyushu University, 744 Motooka Nishi-Ku Fukuoka, 819-0395, Japan

ORCID: https://orcid.org/0000-0001-7883-1427

Abstract

Natural capital defines planetary boundaries and provides a basis for sustainable development. This study reviews previous theoretical developments and confirms that natural capital accounting within the Inclusive Wealth (IW) framework provides a robust link between current capital assets and intergenerational well-being. This study contributes to the literature by combining theoretical advances with practical applications to address criticisms of empirical practice and improve the reliability and scope of cross-country natural capital accounting. An analysis of natural capital levels and changes in 163 economies over the past 30 years reveals significant regional disparities in the decline of global natural capital. In low-income countries, consumption driven by population growth and primary production patterns is severely depleting renewable natural capital. In middle-income countries, urbanization exacerbates natural capital depletion by substituting other forms of capital for natural capital. The wealth status of major G20 economies points to intensive environmental costs and loss of ecosystem services under technological progress, which ignores public ecosystem externalities. This study demonstrates the urgency of natural capital depletion awareness in the management of all economies and highlights the ability of natural capital accounting within the IW framework to inform policy decisions on sustainable growth.

Keywords: Natural capital, Sustainability, Inclusive Wealth, Comprehensive Wealth

1. Introduction

The growing concern about natural capital depletion lies in its impact on global sustainability. Despite its importance, natural capital has long been marginalized in traditional economic models due to the focus primarily on resource allocation and economic growth under market conditions. The difficulty in dealing with natural capital externalities and non-market characteristics, especially in recent years, in response to global issues, such as carbon emissions and ecosystem biodiversity loss, shows the inadequacy of traditional economic approaches. The need to integrate natural capital into the management framework of socioeconomic systems has prompted scholars and policymakers to adopt theoretical frameworks and practices that fully capture the complexity of natural capital.

Natural capital has been extensively discussed by both traditional and ecological economists (Bateman and Mace, 2020; Daly, 2017; Barbier, 2017; Arrow et al., 2012; Helm, Hepburn, and Ruta, 2012; Daly, 2007； Dasgupta, 2000). The Dasgupta Review (2021) marks a paradigm shift in the economic theory of natural capital management by incorporating biodiversity into natural capital and accounting for inclusive wealth (IW). This approach emphasizes intergenerational welfare and highlights the importance of preserving natural capital for future generations. (Priyadarshini et al., 2022; Groom and Turk, 2021). Natural capital management requires a shift in the development of human society from a focus on economic growth to sustainable development. The IW theoretical framework provides a wealth measure of welfare sustainability based on a dynamic economic model that includes natural capital (UNU-IHDP and UNEP, 2014; Managi & Kumar, 2018).

The contributions of this study are as follows: 1) We explain the recent practice of cross-country natural capital accounting within the framework of inclusive wealth theory. The details of accounting practices based on accounting (shadow) prices are clarified, and the scope of countries for statistics is expanded. 2) We discuss inequalities by country in terms of natural capital losses, including renewable, nonrenewable, and public environmental and ecosystem costs. 3) We explore the complex relationship between natural capital and other tangible and intangible forms of capital. Our findings reflect the urgency of addressing the impact of intensified human activities on ecosystems in the context of market distortions in all countries. The inclusive wealth natural capital account is compatible with traditional capital accounts, complements flow-based accounting, provides standards for sustainability assessment, and is used for social cost-benefit analysis of policies or projects.

The next section reviews the theoretical and practical advances in natural capital accounting for sustainable development. Sections 3 and 4 present the basic methodological framework for the empirical accounting. We then present the analysis results based on the latest update of natural capital accounting and conclude with key implications.

2. Literature Review

2.1 Natural capital accounting for sustainability

Natural capital refers to the stock of environmental assets that generates flows of goods and services into the economy (UN, 2020). Understanding natural capital has undergone a paradigm shift in the past decades, recognizing the relationship between natural capital and human welfare and the embeddedness of human socioeconomic activities in nature. The focus of economists has shifted from the depletion of nonrenewable resources and pollution to ecosystem damage and the overstepping of planetary boundaries (Barbier, 2021).

This paradigm shift necessitates revisiting past discussions of sustainability. Global society has gradually realized the ecological degradation and environmental damage caused by population growth and increased consumption. Consequently, international communities and researchers have advocated for the sustainable development of human society (UN, 2015; IPCC, 2014; Rockström et al., 2009). While economists emphasize the incorporation of natural and environmental externalities into the economic framework (Daly, 1997; Arrow et al., 2004; Dasgupta, 2007; Stiglitz, 2009), disparities in understanding natural capital within human socioeconomic activities remain a major obstacle in promoting effective policies and investments to address natural capital issues.

Classical economists believe that technological progress and economic growth are unlimited, and that human society can eventually sustain itself by replacing natural capital with other forms of tangible and intangible capital (Hartwick, 1977; Solow, 1993). In contrast, ecological economists argue that the impacts of rapid population growth and intensified economic activity on Earth's natural systems may exceed their safety and sustainability thresholds (Steffen, 2007, 2015; Folke et al 2021). Humans will, therefore, have to pay a high price to support nature, limit consumption, and keep the Earth's biosphere within sustainable limits (Hickel, 2020; Raworth, 2017; Daly, 1997; Ekins, 2003).

At the root of this debate is the lack of an appropriate measure of natural capital to guide practical global and local problem solving. Traditional economists focus on economic growth, represented by GDP, and the corresponding optimal allocation of resources, often neglecting the non-market- or market-distorting costs of GDP growth. In addition, there is a lack of effective definitions and physical and valuation methods for assessing the loss of natural capital, making it difficult to implement a view that emphasizes the importance of nature. This situation calls for finding natural capital metrics that are compatible with existing economic theories and that go beyond GDP as a measure of sustainability (Stiglitz, 2009).

Natural capital measurement should track and address natural losses caused by economic growth and guide the multi-institutional and multi-dimensional management of natural capital before reaching planetary boundaries. The key to measuring natural capital is to treat it as both a means and an end to human well-being, and to incorporate it into economic growth models (Stiglitz, Fitoussi, and Durand, 2018; Terzi, 2021; Dasgupta, 2021).

Next, we explain the advances in natural capital accounting in relation to well-being.

2.2 Natural capital accounting as Inclusive Wealth

The measurement of human welfare can be traced back to the discussion of the concept of "social income" (Samuelson, 1961; Hicks, 1940). Mirrlees (1969) and Sen (1976) demonstrate the equivalence between real national income and social welfare in a static economic framework. Extending this to a dynamic context, Weitzman (1998) built on Ramsey's ideas, conceptualizing intergenerational welfare as the discounted sum of all intergenerational real national incomes and optimizing the intergenerational utility flow using the net present value (NPV) method. Notably, Weitzman's inclusion of environmental assets in the national accounting system significantly affected the modification of the traditional national income accounting frameworks. This has been part of a broader dialogue in climate economics that considers the uncertainty and risks of environmental change, as seen in models developed by Nordhaus (1991) and further expanded by Stern (2007). Natural capital accounting in the World Bank's genuine savings and national wealth accounting (Daly et al., 2009; Lange et al., 2018), and the development of the System of Environmental-Economic Accounting (SEEA) (UN, 2021) have been informed by Weitzman's foundational contributions emphasizing the incorporation of environmental assets into national accounting frameworks. These initiatives reflect the growing recognition of the importance of natural capital in assessing economic sustainability.

However, the Weitzman model assumes a positive relationship between well-being and consumption, placing sustainability within the context of flow optimization, which challenges market distortions (Stiglitz, 2010). Addressing the non-market nature of natural capital, Dasgupta and Mäler (2000) introduced a nonlinear relationship between current welfare and consumption, establishing an equivalence between intergenerational welfare and wealth. The welfare/wealth equivalence theorem uses shadow (or accounting) prices to value all capital assets, including natural capital, as criteria for intergenerational sustainability and well-being. This approach avoids the discrepancy between NPV valuations based on consumption flow and actual welfare, owing to widespread externalities and the absence of asset markets.

The Dasgupta framework measures the value (change) of capital assets as a productive base composed of tangible (produced) and intangible (human) capital assets as well as natural capital. Accounting prices estimate all capital assets to reflect their real value for well-being (Yamaguchi et al 2022; Hein et al., 2020; Obst et al., 2016). Understanding the interrelations between capital assets and differences between accounting and market prices is crucial for investing in a sustainable future. This approach differs significantly from the System of Environmental-Economic Accounting (SEEA), which is based on the System of National Accounts (SNA) and incorporates the contribution of ecosystem services into economic activities. SEEA uses exchange values as a natural extension of the SNA. These two approaches are complementary, rather than substitutes. In the SEEA context, average accounting prices can also be used for wealth accounting (Hamilton, 2016).

The next section explains the practice of natural capital accounting within the inclusive wealth framework and addresses the current criticisms.

2.3 Inclusive Wealth accounting and Current Criticism

Dasgupta, Arrow, and Mäler (2012) began estimating inclusive wealth (IW) accounts for selected countries, defining IW as the integrated accounting value of economic capital assets. This initiative was expanded in subsequent inclusive wealth reports by the UNU/IHDP-UNEP (2012, 2014) and further extended by Managi and Kumar, marking a significant shift towards a more integrated assessment of national wealth and sustainability through the inclusion of natural capital (Managi & Kumar, 2018). By linking capital assets to Sustainable Development Goals (SDGs), IW can serve as a metric to judge whether countries are adopting policies to achieve, protect, and promote sustainable development (Sugiawan et al 2023; Dasgupta, 2022).

Beyond cross-national natural capital accounting, inclusive wealth accounting methodologies are increasingly applied in specific regions and areas. For example, detailed surveys and natural capital accounting studies have been conducted in India to provide insights into the country's natural capital stock and sustainability (Islam & Managi, 2019). The impact of energy consumption on wealth within the IW framework has been investigated, highlighting the interplay between energy use and sustainable development (Sugiawan & Managi, 2018). Additionally, the use of combined satellite data has enabled more granular investigations at the municipal and provincial levels, providing a clearer picture of the natural capital distribution and changes over smaller geographical areas (Cheng et al., 2022; Zhang et al., 2020; Ikeda et al., 2017, 2019). In a special project, wealth accounting was applied to value groundwater resources, demonstrating the versatility of this approach in evaluating specific natural assets at the micro-level (Fenichel et al., 2016). Moreover, the integration of input-output analysis with wealth accounting has shed light on the impact of regional trade network relationships on the wealth of local economies, demonstrating the ability of accounting to capture complex social wealth gains and losses (Chen et al., 2023).

Despite these advances, the accounting of natural capital in inclusive wealth has been subjected to rigorous scrutiny and criticism (Polasky et al., 2015; Roman & Thiry, 2016; Spash and Hache, 2022). A key point of contention is that the theory of wealth/well-being equivalence, which is based on the resource-allocation mechanism, is unrealistic without incorporating a dynamic modeling framework. Critics also argue that although the importance of accounting prices is affirmed in theory, they may never be reflected in market prices, making it difficult to link theory with empirical work and reducing practical efforts to address natural capital issues. Additionally, the lack of a clear explanation of the characteristics of natural capital, including discussions on the exclusivity and competitiveness of public resources, makes it difficult to attribute natural capital to individual accounts when analyzing intragenerational equity. Furthermore, the incompleteness of natural capital accounting, particularly for ecosystem service functions, is a major concern.

In response to these issues, we have developed recent updates to capital accounting applied in the Inclusive Wealth Report 2023 (UNEP, 2023), which incorporates the latest theoretical advances and aims to improve the consistency of representation from theory to practice. The model is discussed in the next section. These updates address the identified issues and aim to improve the robustness and applicability of natural capital accounting within an inclusive wealth framework.

3. Basic model

This section introduces the concept and model of inclusive wealth (IW). First, we review the theory of wealth and welfare equivalence and explain the global dynamic model with planetary boundaries. We define natural capital and introduce the ecological impact inequality. Finally, we explicitly explain the composition of accounting prices and empirical adjustment of natural capital over time.

3.1 Wealth/Well-being Equivalence Theorem

The wealth–well-being equivalence theory posits that changes in social wealth, represented by a set of capital assets, are directly related to changes in intergenerational welfare. According to Dasgupta (2021), the intergenerational welfare of a socioeconomic system can be expressed as

$$V(\mathbf{K}(\boldsymbol{t})) = \int_t^{\infty} \frac{\Omega(s,t)}{\Omega(t)} N(s) u(c(s, K(s))) e^{-\delta(s-t)} ds, \delta > 0 \,. \quad (1)$$

In Equation (1), N(s) is the population size in period *s*, *u(c(s,K(t)))* is the per capita welfare in period s derived from the consumption flow *c(s,K(s))*, δ is the discount rate of welfare flow, and $\frac{\Omega(s,t)}{\Omega(t)}$ is the probability that the economy survives in period s, given that it survives in period t.

Then, we consider the wealth side, represented as a set of produced capital, human capital, and natural capital, expressed as:

$$W(\boldsymbol{t}) = \sum_i [p_i(t) K_i(t)]. \qquad (2)$$

where term p_i is the accounting price of capital assets and K_i indicates the biophysical quantities of assets of produced, human and natural capital. The Wealth/Well-Being equivalence theorem states that changes in inclusive wealth are equivalent to changes in intergenerational well-being. Mathematically, this relationship can be expressed as:

$$\frac{dW(\boldsymbol{t})}{\boldsymbol{dt}} = \frac{dV(K(t))}{dt}. \qquad (3)$$

Substituting into Equations (2) to (3) yields:

$$\sum_i [p_i \Delta K_i + \Delta p_i K_i] = \sum_i [\partial V(K(t))/\partial K_i(t)] \, \Delta K_i + r(t)\Delta t. \; (4)$$

Let $p_i \equiv \frac{\partial V(K(t))}{\partial K_i(t)}$ and p_i be the link between wealth and intergenerational wellbeing and r(t)=∂V/∂indicates the accounting price of time. Accounting prices p_i can be defined by any future consumption flow: The counterfactual resource allocation mechanism (RAM) shows that by comparing the value of capital asset portfolios arbitrarily assigned by future scenarios with the current condition, we can analyze whether current wealth is on the pathway of sustainability.

Equation (6) further proves that small economic perturbations that increase (or decrease) intergenerational welfare will also increase (or decrease) total wealth if and only if accounting prices remain unchanged. This assumption allows capital assets to be measured empirically at a constant price. We further discuss the definition of natural capital under the principle of wealth and well-being equivalence in the next section, based on a dynamic model with planetary boundaries.

3.2 Global growth model with planetary boundary

The planetary boundary framework developed by Rockström et al. (2009) specified a safe operating space boundary for human activity. To explain the limiting role of this boundary and population growth in human development, Dasgupta (2021) describes global economic activity as embedded in ecosystems in a global economic model that includes produced, human, and natural capital. He denoted the total stock of ecosystems as *S*, which provides both provisioning services for production activities and public services to regulate and maintain the human living environment. The production function can be expressed as

$$Y = Ny = AS^{\beta}K^{a}H^{b}R^{(1-a-b)} . (5)$$

where N represents the population, *y* is the per capita demand, *R* is the flow of provisioning services, and S^{β} denotes public regulating and maintenance services. The combination factor $K^{a}H^{b}R^{(1-a-b)}$ is in the traditional Cobb-Douglas form, *K* is produced capital, and *H* = *Nh* is human capital. *A* represents public technological progress. Equation (5) shows that global production is limited by S^{β}, regardless of technological progress, and the degradation of S^β will drag production to a downward trend.

Considering the balance between supply and consumption, let a_x be a numerical measure of the efficiency of the conversion of biosphere products and services into global GDP and let a_z be a numerical measure of the degree to which the biosphere is converted into global waste. Let G(S) be the regeneration rate of the ecosystem, and the prerequisite for sustainability be

$$\mathrm{I} = R + \frac{Ny}{a_z} = \frac{Ny}{a_x} + \frac{Ny}{a_z} = \frac{Ny}{a} = G(S). \quad (6)$$

Here, $\frac{Ny}{a}$ is the Ehrlich-Holderlen Equation, representing the consumption impact and the global ecological footprint. In addition to the discussion of conventional nonrenewable and renewable capital, Equations (5) and (6) make this framework applicable to measuring global negative environmental capital $\frac{Ny}{a_z}$, such as the impact of Co2 emission from fossil fuel combustion. Additionally, total factor productivity (TFP) is expressed as AS^{β}, showing that not considering the externality of natural capital regulation services may overestimate production technology because the excessive consumption of natural capital caused by economic growth is wrongly attributed to technological progress.

The Equations above explain the dynamic model framework for natural capital participation. In a perfect market, the accounting price of natural capital flows is obtained by using the Hamiltonian equivalent. Consequently, this applies to the accounting price of capital asset stocks. However, distortion and incomplete market conditions cause the accounting price of natural capital to deviate from optimized conditions. In the next section, we explain the accounting prices of natural capital under imperfect market conditions and with time-varying adjustments.

3.3 Accounting price of natural capitals and adjustments

According to Equation (1), the accounting price of capital assets can also be expressed as

$$p_i = \int_t^{\infty} \frac{\Omega(s)}{\Omega(t)} N(s) u'\left(c\big(s, K(s)\big)\right) \frac{\partial c\big(s, K(s)\big)}{\partial K_i} e^{-\delta(s-t)} ds. \quad (7)$$

This Equation shows the relationship between the accounting price of inclusive wealth and the net present value (NPV) of the welfare and consumption flow of society. When the economy is in a steady state and the market is optimized, the accounting price of the asset is equal to the NPV of the optimized consumption flow measured by the market price.

However, natural capital often lacks markets or suffers from serious distortions. Therefore, the relationship between the accounting price and market price can be expressed as:

$p_i = q_i + e_i$. (8)

where q_i is the market price, and e_i is the marginal external value of unit capital *i*. If the market price is zero, then the accounting price is equal to the external value. If there is a difference between the accounting and market prices, capital investment may be inappropriate or overused. This relationship forms the basis of empirical accounting of natural capital.

The accounting price also shows the arbitrage conditions for substitution. The marginal cost of substituting capital assets increases significantly when the stock of natural capital reduces to a critical level. This implies that substitution requires a much higher price, suggesting that even natural capital that provides support services is not substitutable.

Long-term changes in accounting prices affect sustainability and must be considered. Dasgupta defines a separate category of capital as enabling assets such as public knowledge, institutional and social trust, and biodiversity, which are reflected in changing accounting prices. The introduction of allowing assets is theoretically rigorous, but there are insurmountable difficulties in directly measuring them. Instead, estimating the accounting price change can be replaced by valuing the change over time, as shown in Equation (4). The effect of the accounting price change is equal to the value of the change over time, according to the wealth and welfare equivalence principle. Arrow et al. (2012) explained that asset changes are time-varying adjustments, interpreted as total factor productivity (TFP) growth, damage from CO2 emissions, and oil gains from oil price changes. Therefore, we consider time-varying public capital as *G(t)*, and global welfare can be expressed as:

$V(t) = \sum_n V_n(t) = \sum_n V_n(k_n(t), G(t))$. (9)

Where $V_n(t)$ denotes the welfare of country n. Therefore, the valuation of enabling assets can be explained by the change over time, based on the global and regional characteristics of natural capital (excludability and rivalry). Based on the above model overview, we describe below the assumptions about natural capital stocks and prices in the cross-country wealth accounting practice and the latest data included in the update.

4 Updating natural capital accounting as inclusive wealth

This section describes the updated cross-country natural capital accounting for the Inclusive Wealth Report 2023 (UNEP 2023). We first outline the basic framework of natural capital accounting, present the specific accounting scheme and related hypotheses in this update, and state its limitations.

4.1 The characteristic of natural capital and adjustments

This update proposes a detailed framework that further emphasizes the characteristics of each type of natural capital and adjustment, as summarized in Table 1. The characteristics of natural capital include excludability, rivalry, market prices, and externalities. Current natural capital accounting includes five main categories.

Agricultural land: renewable resources providing food and animal products (R). Given the excludability and rivalry of agricultural land, their accounting prices are determined by the market prices. Agricultural activities have negative externalities such as greenhouse gas emissions from deforestation and manure, which are accounted for separately.

Fish stocks: Renewable resources that provide non-excludable and rivalrous fish (R), making them vulnerable to overexploitation (tragedy of the commons). Accounting price of fish stocks depending on fish market value.

Forests: Renewable resources providing timber (R) and ecosystem services (S^{β}). Timber is non-excludable and rivalrous and has market value. Ecosystem services are non-excludable, non-rivalrous, and have significant non-market externalities.

Mineral ores: Mineral ores are non-renewable resources that provide provisioning services(R) and have prices and negative externalities. For capital asset accounting, only the market value is considered, and the environmental externalities in production are calculated separately.

Fossil fuels: nonrenewable provisioning services(R) that have market value and negative environmental externalities. The externalities and impacts of price changes were calculated separately.

Adjustments: Fossil fuel and agricultural land externalities were calculated as the CO2 damage. Oil price changes due to the trade structure and institutional capital factors were calculated as oil price gains and losses based on oil exports and consumption. TFP includes the changes in public knowledge and global public ecosystem services (S^{β}).

Based on the explicit characterization of different types of natural capital in Table 1, assumptions in natural capital accounting can be operated within a consistent framework. We explain the latest accounting updates, including the data and methodological specifications.

[Insert Table 1 here]

4.2 Data and empirical assumption

Cross-country natural capital accounting includes estimating the biophysical quantities and accounting prices for each capital by country. We present the calculation methods, related assumptions, and data updates for the various types of capital.

Agricultural land includes arable land and pasture. A unified method was used for these calculations. Permanent arable land and pasture area data from the Food and Agriculture Organization of the United Nations (FAO 2020) were used to estimate the agricultural land of each country. The net present value (NPV) of the annual service flow per hectare was calculated based on the weighted average of the crop price by crop yield and land rental rate and applied as the accounting price of agricultural land.

Forest resources include only natural forests because artificial forests are assumed to be produced capital. For the market value of forests, we calculate the timber inventory quantities based on the total area of forests, forest types, and growth time and apply the weighted country-specific average timber prices and rental rates to estimate the accounting prices. To calculate the NPV, the accounting price is calculated based on the timber prices of various countries, import and export weights, and rental rates. For the non-market value of natural forests, only a certain proportion of the total forest area related to human activities is considered natural capital, and the price is estimated based on the ecosystem service valuation (ESVD,2019; TEEB, 2010) and forest-type weights.

Marine fish capital has the characteristics of a common pool resource; however, for ease of calculation, we allocated fish capital to fishing countries according to capture weights. The estimation of fish capital stock must consider the intrinsic growth rate (r) and carrying capacity of the resource stock (k). The method proposed by Martell and Froese (2013) was used. This method uses a uniform distribution function to generate a feasible (r, k), which is estimated using the Bernoulli distribution. The accounting prices of fish capital were calculated as the NPV based on the weighted average market price of different fish species and rental rate.

Fossil fuels and minerals are finite resources, and we estimated the inventory time series based on the most recent stock and annual production estimates for each country. Inventory data for fossil fuels were obtained from the US Energy Information Administration (2020). Inventories of the top ten minerals (bauxite, copper, gold, iron, lead, nickel, phosphates, silver, tin, and zinc) were based on the US Geological Survey (2021) survey data. For resources that have not yet been extracted, it is more appropriate to use rental prices, which are the net costs of extraction, to estimate their value; however, such data are difficult to obtain. Following Arrow et al. (2012), we assume that the rental rate of the total price is constant and obtain price data from major markets to estimate the average market price. Fossil fuel prices were taken from the BP Statistical Review of World Energy (2021) and mineral price data from the US Geological Survey (2021). Rental prices were estimated by multiplying the corresponding sector rental rate by the average market price (Narayanan et al., 2012).

Adjustments were estimated based on their characteristics. For carbon damages, we calculate annual global carbon damages based on global emissions from fuel consumption, cement production, deforestation, and the fixed cost of carbon damage, and then allocate the global damages to countries according to the framework provided by Nordhaus and Boyer (2000) based on the weight of the impact of climate change by each country. For the oil gain, we assume that the price of oil rents increases by 3% per year on average from 1990 to 2020, calculate the total oil gain, and then allocate the gain to exporting countries and the loss to net importing countries. For total factor productivity (TFP), we calculate the annual rate of change to adjust for per capita wealth. The estimation of TFP was based on the method of Olley and Pakes (1996), and TFP includes changes in public ecosystem services and technological progress.

Detailed estimation Equations and data are provided in the Supporting Information. Below, we discuss the limitations of current accounting.

4.3 Limitations

Although the theoretical underpinnings of inclusive wealth are sound, we must make some cuts to the actual estimation. This is not to cut corners, but because inclusive wealth is intended to provide indicators for sustainability analysis rather than a comprehensive accounting system. Based on the expectations of future scenarios in cross-border accounting, the relationship with actual capital changes can help us apply inclusive wealth indicators to social cost-benefit analysis or economic policy analysis to obtain information on the wealth impact of promoted investment projects or policies.

However, we recognize shortcomings in current natural capital accounting. For example, we need to calculate the value of ecosystems other than forests, such as the blue carbon stocks in marine ecosystems. In addition, the pollution externalities associated with mineral resources have not developed further.

The accounting of natural capital externalities, particularly enabling assets, needs to be further discussed. Given the complexity of ecosystems, specific methods for certain types of capital must be considered for specific services.

Despite some shortcomings, the latest update of Cross-Border Inclusive Wealth has extended the coverage of accounts from 144 to 163 countries, improving data reliability and increasing the scope of the assessment. In the next section, we analyze the impact of natural capital on national and global sustainability based on the relationship between natural capital and wealth, and between natural capital and GDP.

5. Empirical Findings and discussion

This section presents the main results of the cross-national integrative wealth accounting. We focus on the implications of changes in natural capital for sustainability, particularly evidence beyond GDP on inequalities in wealth accumulation caused by uneven capital depletion and accumulation.

5.1 Global wealth and natural capital depletion.

We begin with a discussion on global inclusive wealth, highlighting the threat to natural capital and global sustainability from current population activities that are not captured by income growth. We focus on changes in per capita wealth to reflect the real level of wealth of the population. Figure 1 (left) shows the changes in per capita wealth by capital asset over the last 30 years for 163 countries, covering 99% of the global GDP and 98% of the world's population. The results show that, on average, natural capital was the most important asset in 1990, accounting for more than 50% of per capita wealth, followed by human capital and produced capital. This structure of per capita wealth changed over time, with a significant decline around the 2000s and an increase since the 2010s. The main reason for this decline in wealth is a significant decrease in natural capital. Natural capital per capita fell to 28%. Meanwhile, the share of human capital in wealth surpassed that of natural capital in the 2000s, making human capital the most important asset. In contrast to the continuous growth trend in GDP per capita, wealth per capita has declined, and will still be 4% lower in 2020 than in the 1990s. Wealth accounting shows that the cost of natural capital leads to a decline in the wealth.

Figure 1 (right) compares the absolute changes in per capita capital across these three periods. In the first period (1990-2000), the significant decrease in renewable capital (-10000 2015 USD) was the main reason for the loss of natural capital, followed by nonrenewable capital. In the following period, the trend of natural capital loss, both renewable and nonrenewable, was reduced. In particular, in the 2010s, the reduction in the loss of renewable capital and the continued accumulation of productive and human capital were the reasons for wealth recovery. However, the accumulation of negative environmental costs owing to carbon emissions continued during all three periods.

[Insert Figure 1 here]

Figure 2 shows the changes in each capital asset in per-capita terms from 1990 to 2020. As shown in Figure 2 (left), produced capital increases the most, by 200%, compared to the 1990 levels, and human capital increases by over 140%. On the other hand, almost 50% of natural capital per capita is lost, with nonrenewable natural capital depleting faster in the early stages and renewable natural capital depleting more slowly.

Global capital accumulation is influenced by changes in international social attitudes and patterns of economic activity. Figure 2 (right) shows that natural capital depletion increased rapidly in the 1990s. However, after the Kyoto Protocol in 1997, the loss of natural capital was curbed to some extent. After 2008, the global financial crisis caused a shift in the economic model. The production of capital accumulation plummeted, and the loss of natural capital was further mitigated. Renewable natural capital was significantly mitigated and became positive in the 2010s. The recent COVID-19 pandemic led to significant changes in wealth accumulation, the stagnation of international economic activity caused the accumulation of productive capital to decline again, and human capital loss showed the impact of the pandemic. Meanwhile, the use of nonrenewable capital fell because of the decline in economic activity.

In the next section, we discuss the differences in natural capital changes among countries and their implications for their economies.

[Insert Figure 2 here]

5.2 Detail of natural capital change and Adjustment.

We discuss changes in wealth and natural capital by country. Figure 3 depicts the relationship between the average GDP change per capita and wealth or natural capital growth between 1990 and 2020. The 163 countries are grouped into low-income, low-middle, and high-middle groups, according to the classification of income groups following the World Bank's grouping. We separated G20 economies into groups based on the proportion and growth rate of these economies, accounting for world GDP exceeding 80%.

Figure 3(left) shows that GDP growth does not guarantee growth in wealth. Only 89 countries, most of which are G20 economies, achieved GDP and wealth growth. Fifty-three countries experienced a decline in wealth and GDP growth, mainly in low- and middle-income countries. More than half of the countries that experienced GDP and wealth decline were low-income countries. Furthermore, as shown in Figure 3 (right), most countries experienced a significant decrease in natural capital when GDP grew, except for a few Central and Northern European countries, which showed increased per capita natural capital due to population decline.

[Insert Figure 3 here]

Figure 4 illustrates the details of the natural capital depletion in countries with different income groups. In low- and middle-income countries, the largest losses are in agricultural and forest capital, due to excessive population growth and economies heavily dependent on primary agriculture. Even if forest land were substituted for agricultural land, rapid population growth would outstrip the increase in agricultural capital, making it impossible to maintain per capita capital levels. Middle-income countries have experienced the greatest loss of natural capital, which may be related to capital substitution and increased consumption caused by urbanization in these countries over the past 30 years. High-income and G20 countries show an apparent loss of fossil fuel natural capital related to an industrialized economy, with higher consumption levels in these countries. The market for renewable natural capital in these countries has increased over the last decade, and only the loss of non-market ecosystem services has continued. Moreover, the adjustment terms show that high-income countries have benefited considerably from the oil trade, while the G20 countries have increased oil losses and carbon dioxide damage.

The results show that loss of natural capital has serious implications for sustainable national development. Rapid population growth further depletes natural capital, leading to limited GDP growth, particularly in low-income countries. In middle-income countries undergoing industrialization and urbanization, the structure of wealth is changing and natural capital is being replaced by other capital. However, the rapid loss of natural capital indicates that their development potential is constrained, which affects the sustainability of existing development gains. In high-income and G20 countries, the reduction of natural capital loss is positively related to GDP growth, implying that these countries are saving natural capital as the structural transformation of their economies shifts towards the conservation of natural capital. In the next section, we analyze the depletion of natural capital under different wealth structures of industrialized and urbanized countries and the relationship between the improvement in total factor productivity (TFP) and the depletion of natural capital.

[Insert Figure 4 here]

5.3 Capital Substitution under Market Distortion

We also discuss how urbanization and technological progress are related to natural capital depletion, and how they affect sustainability. Using PC and HC per capita in 1990 as indicators, Figure 5 shows the relationship between the initial level of capital accumulation and the loss of renewable and nonrenewable natural capital. We find that, except for low-income countries, the higher the level of urbanization, the higher the rate of loss of nonrenewable natural capital, especially in middle- and high-income countries. However, except for middle- and high-income countries, the loss of renewable natural capital tends to decrease with increasing urbanization. The above results seem to illustrate the conclusion of the Kuznets curve that the inevitable costs of environmental and natural capital in the industrial process are mitigated as income reaches the level of paying back these costs.

However, a comparison of actual rates of natural capital loss across groups shows that while G20 countries have lower rates of renewable natural capital loss, the rate of natural capital loss in high-income groups is not lower than that in low-income groups. This finding shows that natural capital is necessary at all stages of development, and is not a luxury cost for urbanized economies. Both the investment and management of natural capital are critical in all countries.

[Insert Figure 5 here]

Figure 6 shows the relationship between changes in TFP and losses in natural capital. As explained in the previous section, TFP includes the impact of changes in public ecosystem services. The results show an almost linear relationship between TFP growth and the loss of natural capital. The loss of nonrenewable resources has declined more in high-income countries. By contrast, the rate of loss declined in the G20 countries, suggesting that resource-conserving technological progress tends to conserve resources in these large countries under market-based resource conditions. However, for non-market or natural capital, technological progress leads to increased losses that are not accounted for.

As shown in the previous results, the loss of natural capital has the greatest impact on low- and middle-income countries, directly affecting their wealth accumulation. In particular, the loss of natural capital in low-income countries directly affects their sustainable development path. Even in middle-income countries that have embarked on industrialization, it must be considered that excessive loss of natural capital will affect the long-term sustainable development of these countries because the share of natural capital in the wealth that is replaced has fallen significantly, increasing the cost of accumulating other productive or human capital. Although G20 countries have taken a step forward and considered the technological progress of market-based capital to help mitigate the loss of natural capital, the increasing environmental costs and limits of ecosystems under non-marketization will strongly affect the sustainability of these countries and the world.

[Insert Figure 6 here]

6. Conclusion

Incorporating natural capital accounting into dynamic economic models is crucial for sustainable development assessment and management. The main objective of this study is to illustrate the latest updates in the inclusive wealth of cross-country natural capital accounts. We aimed to clarify the link between theoretical models and practical applications, and to improve the accuracy and scope of accounting. First, by explaining the theoretical model, we clarify the relationship between accounting prices, the key to the capital welfare equivalence principle, consumption flows, market prices, and externalities. Second, we provide details on assessing the prices of natural capital in practical accounting, including estimating the impact of enabling assets on accounting prices, and evaluating negative environmental costs. In addition, we clearly defined the distribution of common pools and public goods to different economies at the national level, thereby clarifying the reliability of the analysis of regional inequality in wealth and natural capital.

Our analysis of the changes in wealth and natural capital in 163 countries over the past three decades shows that, contrary to the results using GDP as an indicator, today, the world is not necessarily on a more prosperous path than in the past. The depletion of natural capital has reduced global wealth over the last century and in the early 21st century, although the rate of loss has slowed in the past decade. This is linked to the current social consciousness and structural economic changes. However, the environmental costs of carbon dioxide emissions related to climate change continue to rise.

The risks of natural capital deletion on sustainable development are particularly pronounced in low- and middle-income countries. Population growth has increased consumption effects on resource degradation, and urbanization and industrialization have exacerbated these losses. While productivity has improved and the loss of market-based nonrenewable resources has slowed in the major G20 economies, technological progress is overestimated due to a lack of awareness of the risks of reaching planetary boundaries. These results highlight the importance of natural capital management for global and local economies at all development and income levels, and not just as a post-development consideration.

With these recent theoretical and practical updates, we respond to previous criticisms of the practical application of inclusive wealth accounting. However, we acknowledge that omissions are inevitable in natural capital accounting, and that the scope of accounting needs further expansion, particularly in valuing ecosystems and externalities. This includes the consideration of the negative impacts of air pollution, the role of water ecosystems, and blue carbon in carbon sequestration. Furthermore, applying natural capital accounting to micro-level analyses is crucial for achieving sustainable development goals (SDGs). It provides precise policy and investment guidance, helping to evaluate whether production or organizational activities result in social benefits or losses.

Nevertheless, Inclusive wealth provides a robust framework for evaluating natural capital. Accounting prices, which include market value and externalities, are critical to natural capital accounting because they link intergenerational welfare and capital equivalence. Updated natural capital accounting can be a powerful analytical tool for sustainability assessment, helping decision makers or groups assess whether policies or activities are consistent with sustainable development principles.

Declarations

Consent for publication: Not applicable.

Availability of data and material: The data is available upon reasonable request.

Competing interests: The authors declare that they have no competing interests.

Author contributions: SC conducted the analyses, prepared the primary manuscript, and revised the manuscript. SM supervised the writing of the manuscript.

Acknowledgment: Not applicable.

Funding: This research was supported by the Environment Research and Technology Development Fund (JPMEERF20201001) of the Environmental Restoration and Conservation Agency of Japan, and JSPS KAKENHI (Grant Number JP20H00648). This study was supported by JSPS KAKENHI (grant number JP20H00648).

Ethical Compliance: All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

References

Center, B. P. (2020). Annual energy outlook 2020. *Energy Information Administration, Washington, DC, 12*, 1672-1679.

Arrow, K. J., Dasgupta, P., Goulder, L. H., Mumford, K. J., & Oleson, K. (2012). Sustainability and the measurement of wealth. *Environment and Development Economics, 17*, 317–353.

Arrow, K., Dasgupta, P., Goulder, L., Daily, G., Ehrlich, P., Heal, G., . . . Walker, B. (2004). Are we consuming too much? *Journal of Economic Perspectives, 18,* 147–172.

Barbier, E. B. (2017). The concept of natural capital. *Oxford Review of Economic Policy, 33*, 157–170.

Barbier, E. B. (2021). The evolution of economic views on natural resource scarcity. *Review of Environmental Economics and Policy, 15*, 24–44.

Bateman, I., & Mace, G. (2020). The natural capital framework for sustainable, efficient and equitable decision making. *Nature Sustainability, 3,* 776–783. doi:10.1038/s41893-020-0552-3

Brander, L. M., de Groot, R., Guisado Goñi, V., van 't Hoff, V., Schägner, J. P., Solomonides, S., . . . Sinclair, M. (2024). *Ecosystem Services Valuation Database (ESVD).* Tech. rep., Foundation for Sustainable Development and Brander Environmental Economics. Retrieved from https://www.esvd.net/

Chen, S., Kurita, K., Wakiyama, T., Kagawa, S., & Managi, S. (2023). Inclusive wealth footprint for cities in Japan: regional clusters for sustainable development. *Sustainability Science, 18*, 2293–2307.

Cheng, D., Xue, Q., Hubacek, K., Fan, J., Shan, Y., Zhou, Y., & Zhang, X. (2022). Inclusive wealth index measuring sustainable development potentials for Chinese cities. *Global Environmental Change, 72*, 102417.

Daly, H. E. (1997). *Beyond Growth: The Economics of Sustainable Development.* Beacon Press.

Daly, H. E. (2017). Toward some operational principles of sustainable development. In *The economics of sustainability* (pp. 97–102). Routledge.

Daly, H. E., & Farley, J. (2009). *Ecological Economics: Principles and Applications.* Island Press.

Dasgupta, P. (2000). *Valuing biodiversity.* The Nature Conservancy.

Dasgupta, P. (2007). *Economics: A Very Short Introduction.* Oxford University Press.

Dasgupta, P. (2021). *The Economics of Biodiversity: The Dasgupta Review.* Tech. rep., HM Treasury. Retrieved from https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review

Dasgupta, P., Managi, S., & Kumar, P. (2022). The inclusive wealth index and sustainable development goals. *Sustainability Science, 17*, 899–903.

Ekins, P. (2003). Identifying critical natural capital: Conclusions about critical natural capital. *Ecological Economics, 44*, 277–292.

Fenichel, E. P., Abbott, J. K., Bayham, J., Boone, W., Haacker, E. M., & Pfeiffer, L. (2016). Measuring the value of groundwater and other forms of natural capital. *Proceedings of the National Academy of Sciences, 113*, 2382–2387.

Folke, C., Polasky, S., Rockström, J., Galaz, V., Westley, F., Lamont, M., & Walker, B. H. (2021). Our future in the Anthropocene biosphere. *Ambio, 50*, 834–869.

Food, & of the United Nations, A. O. (2020). *FAOSTAT database.* FAO.

Groom, B., & Turk, Z. (2021). Reflections on the Dasgupta Review on the Economics of Biodiversity. *Environmental and Resource Economics, 79*, 1–23.

Hamilton, K. (2016). Measuring sustainability in the UN system of environmental-economic accounting. *Environmental and Resource Economics*, *64*, 25–36.

Hartwick, J. M. (1977). Intergenerational equity and the investing of rents from exhaustible resources. *American Economic Review, 67*, 972–974.

Hein, L., Bagstad, K. J., Obst, C., Edens, B., Schenau, S., Castillo, G., . . . Caparrós, A. (2020). Progress in natural capital accounting for ecosystems. *Science, 367*, 514–515. doi:10.1126/science.aaz8901

Helm, D., Hepburn, C., & Ruta, G. (2012). Trade, climate change, and the political game theory of border carbon adjustments. *Oxford Review of Economic Policy, 28*, 368–394.

Hickel, J., & Kallis, G. (2020). Is green growth possible? *New Political Economy, 25*, 469–486.

Hicks, J. R. (1940). The valuation of the social income. *Economica, 7*, 105–124.

Ikeda, S., Managi, S., & Zhang, W. (2017). Evaluating the impact of urbanization on natural capital and human welfare. *Ecological Indicators, 77*, 218–225.

Islam, M. Z., & Managi, S. (2019). Assessing natural capital and sustainability in India: A regional analysis. *Journal of Environmental Management, 233*, 790–800.

Lange, G.-M., Wodon, Q., & Carey, K. (2018). *The Changing Wealth of Nations 2018: Building a Sustainable Future.* World Bank Publications.

Managi, S., & Kumar, P. (2018). *Inclusive Wealth Report 2018: Measuring progress toward sustainability.* Routledge.

Mirrlees, J. A. (1969). The Theory of Moral Hazard and Unobservable Behaviour: Part I. *Review of Economic Studies, 66*, 3–21.

Narayanan, B., Aguiar, A., & McDougall, R. (2012). *Global Trade, Assistance, and Production: The GTAP 8 Data Base.* Center for Global Trade Analysis, Purdue University.

Nations, U. (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development.* United Nations.

Nations, U. (2020). *System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting.* United Nations.

Nations, U. (2021). *System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA).* United Nations.

Nordhaus, W. D. (1991). To slow or not to slow: The economics of the greenhouse effect. *The Economic Journal, 101*, 920–937.

Obst, C., Hein, L., & Edens, B. (2016). National accounting and the valuation of ecosystem assets and their services. *Environmental and Resource Economics, 64*, 1–23.

Olley, G. S., & Pakes, A. (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. *Econometrica, 64*, 1263–1297.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., & van Ypserle, J.-P. (2014). *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change.* Tech. rep., IPCC.

Polasky, S., Bryant, B., Hawthorne, P., Johnson, J., Keeler, B., & Pennington, D. (2015). Inclusive wealth as a metric of sustainable development. *Annual Review of Environment and Resources, 40*, 445–466.

Priyadarshini, P., Bundela, A. K., Gaspar Atos, A., Stringer, L. C., Dhyani, S., Dasgupta, R., & Penuelas, J. (2022). Advancing global biodiversity governance: recommendations for strengthening the post-2020 global biodiversity framework. *Anthropocene Science, 1*, 195–203.

Priyadarshini, P., Dubey, P. K., Singh, A., Chaurasia, R., & Abhilash, P. C. (2022). The Dasgupta review: resetting the stage for a new paradigm. *Frontiers in Ecology and the Environment, 20*, 240–246.

Programme, U. N. (2023). *Inclusive Wealth Report 2023: Measuring Sustainability and Equity.* Tech. rep. Retrieved from https://wedocs.unep.org/20.500.11822/43131

Raworth, K. (2017). *Doughnut economics: Seven ways to think like a 21st-century economist.* Chelsea Green Publishing.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E. F., & Foley, J. A. (2009). A safe operating space for humanity. *Nature, 461*, 472–475.

Roman, P., & Thiry, G. (2016). The inclusive wealth index. A critical appraisal. *Ecological Economics, 124*, 185–192.

Samuelson, P. A. (1961). *Foundations of Economic Analysis.* Harvard University Press.

Sen, A. K. (1976). Real National Income. *Review of Economic Studies, 43*, 19–39.

Solow, R. M. (1993). Sustainability: An Economist's Perspective. In *Economics of the Environment: Selected Readings* (pp. 179–187). W.W. Norton & Company.

Spash, C. L., & Hache, F. (2022). The Dasgupta Review deconstructed: An exposé of biodiversity economics. *Globalizations, 19*, 653–676.

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., & Ludwig, C. (2015). The trajectory of the Anthropocene: the great acceleration. *The Anthropocene Review, 2*, 81–98. doi:10.1177/2053019614564785

Steffen, W., Crutzen, P. J., & McNeill, J. R. (2007). The Anthropocene: are humans now overwhelming the great forces of nature. *Ambio-Journal of Human Environment Research and Management, 36*, 614–621.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*, 1259855.

Stern, N. (2007). *The Economics of Climate Change: The Stern Review.* Cambridge University Press.

Stiglitz, J. E. (2009). GDP fetishism. *Economist's Voice, 6*, 5.

Stiglitz, J. E., Fitoussi, J.-P., & Durand, M. (2018). *Beyond GDP: Measuring What Counts for Economic and Social Performance.* OECD Publishing.

Stiglitz, J. E., Sen, A., & Fitoussi, J.-P. (2010). *Mismeasuring Our Lives: Why GDP Doesn't Add Up.* The New Press.

Sugiawan, Y., & Managi, S. (2018). The impact of energy consumption on wealth. *Energy Economics, 75*, 575–587.

Sugiawan, Y., Kurniawan, R., & Managi, S. (2023). Assessing the United Nations sustainable development goals from the inclusive wealth perspective. *Scientific Reports*, *13*, 1601.

Survey, U. G. (2021). *Mineral commodity summaries 2021*. US Geological Survey. doi:10.3133/mcs2021

TEEB. (2010). *The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations.* Earthscan.

Terzi, S. (2021). Rethinking capital and sustainability: An appraisal of the Inclusive Wealth Index. *Sustainability Science*, *16*, 893–904.

UNU-IHDP, & UNEP. (2012). *Inclusive Wealth Report 2012: Measuring Progress Toward Sustainability.* Cambridge University Press.

UNU-IHDP, & UNEP. (2014). *Inclusive Wealth Report 2014: Measuring Progress Toward Sustainability.* Cambridge University Press.

Weitzman, M. L. (1998). Recombinant growth. *The Quarterly Journal of Economics, 113*, 331–360.

Yamaguchi, R., Islam, M., & Managi, S. (2023). Natural capital and wealth accounting for sustainability assessment: A global perspective. *International Review of Environmental and Resource Economics, 16*, 431–465.

Zhang, W., Ikeda, S., & Managi, S. (2020). Satellite data and natural capital accounting: A case study of China's provinces. *Remote Sensing of Environment, 239*, 111646.

Tables

Table 1 Characteristics of natural capital

Natural capital accounting	**Provisioning services (R) / regulation and maintenance services (Sβ)**	**Finite or regenerative**	**Excludability**	**Rivalry**	**Market price**	**Externality**
Agricultural land	crops, livestock (R)	regenerative	Excludable	Rivalrous	X	*
Fish stock	fish (R)	regenerative	Non-Excludable	Rivalrous	X	/
Forest(market)	timber '(R)'	regenerative	Non-Excludable	Rivalrous	X	/
Forest(non-market)	ecosystem service (S^{β})	regenerative	Non-Excludable	Non-Rivalrous	/	X
Mineral ore	minerals and metals (R)	finite	Excludable	Rivalrous	X	*
Fossil fuel	fossil fuels (R)	finite	Excludable	Rivalrous	X	*#
Adjustments						
CO2 damage	/	/	Non-Excludable	Rivalrous		X
Oil gain	/	/	Excludable	Rivalrous	X	
TFP						

* Because CO2 emissions from fossil fuel combustion, cement production, and agricultural activities have the characteristics of a negative public good, their externality is included as a separate adjustment for CO2 damage.

#Oil gains from oil price increases differ between importers and exporters and are calculated separately as the role of enabling assets, such as institutional capital.

(X) Global ecosystem regulation and maintenance services are incorporated into the TFP estimation.

Figures

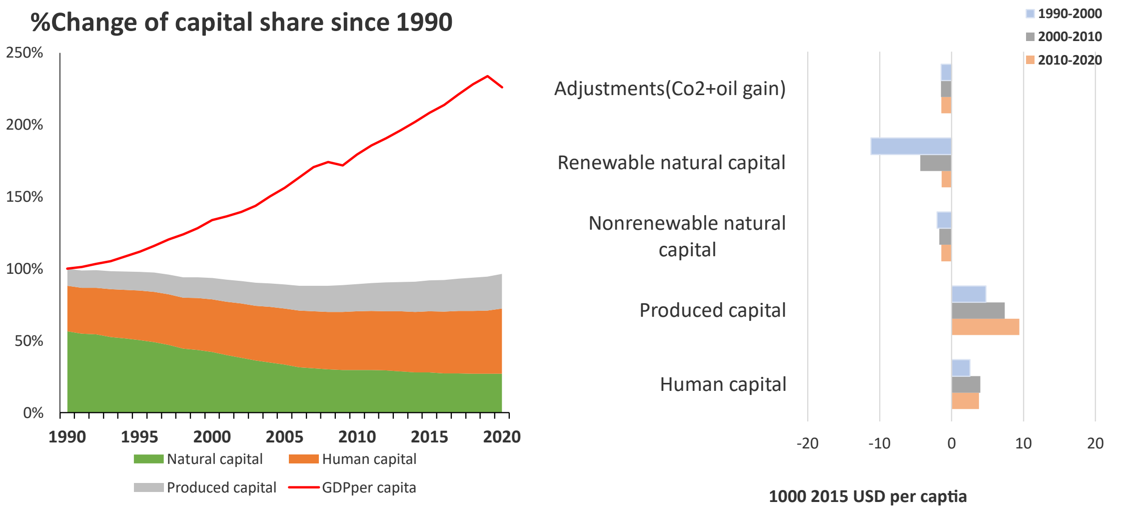

Figure 1. Change in Inclusive wealth per capita by capital assets ratio and absolute changes for three decades.

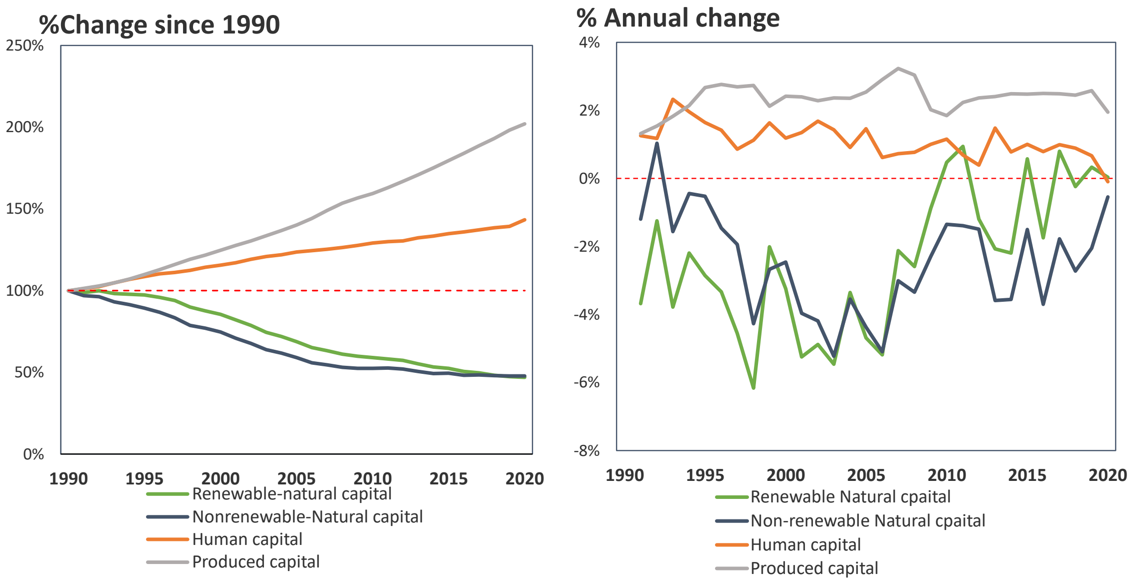

Figure 2. Change in capital assets per capita since 1990 and annual change.

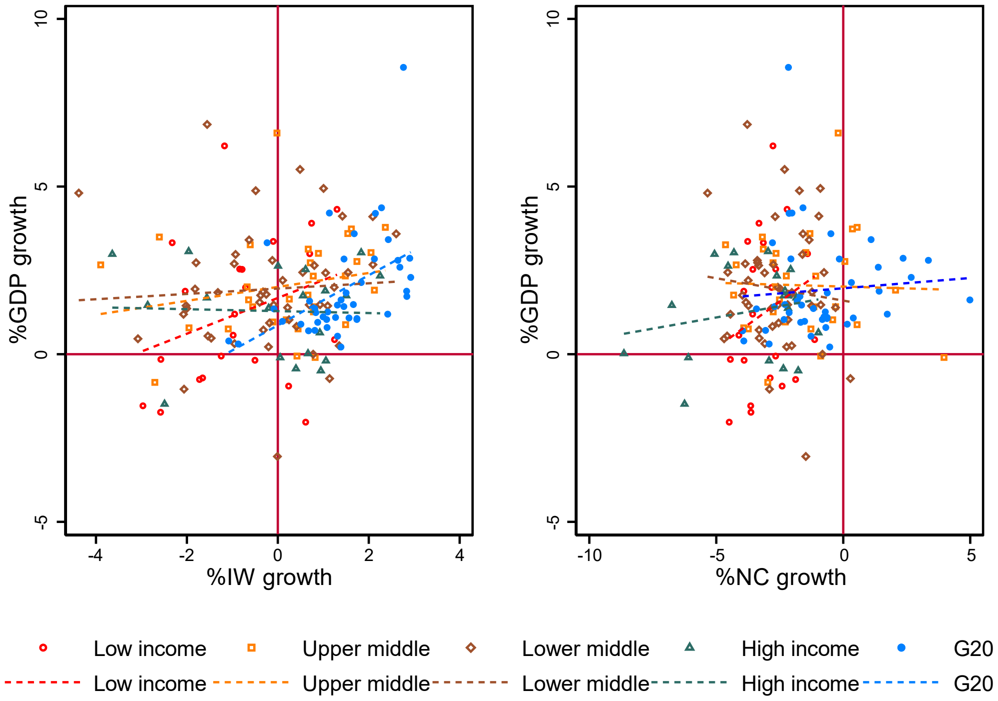

Figure 3. GDP per capita growth vs. IW per capita and natural capital change by income group for the period 1990-2020.

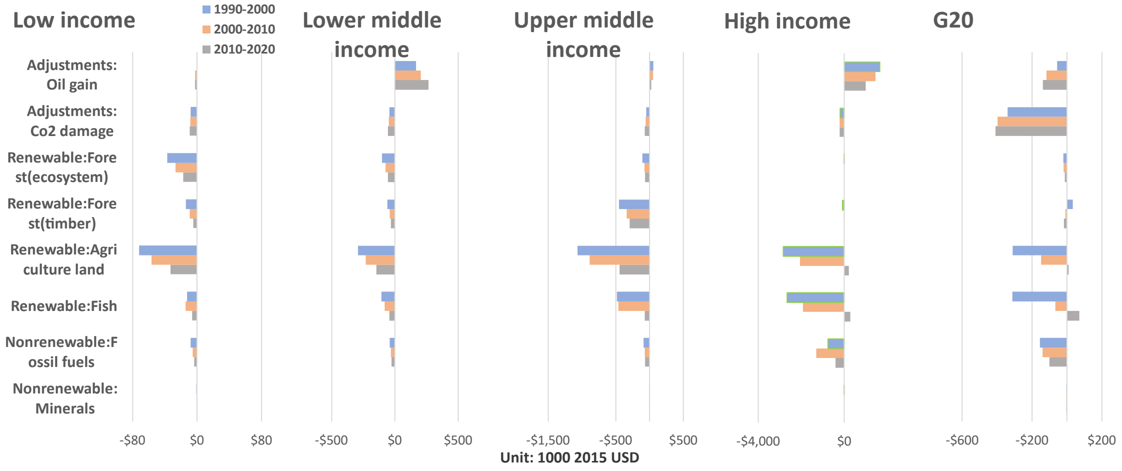

Figure 4. Detailed changes in per capita natural capital over three different decades.

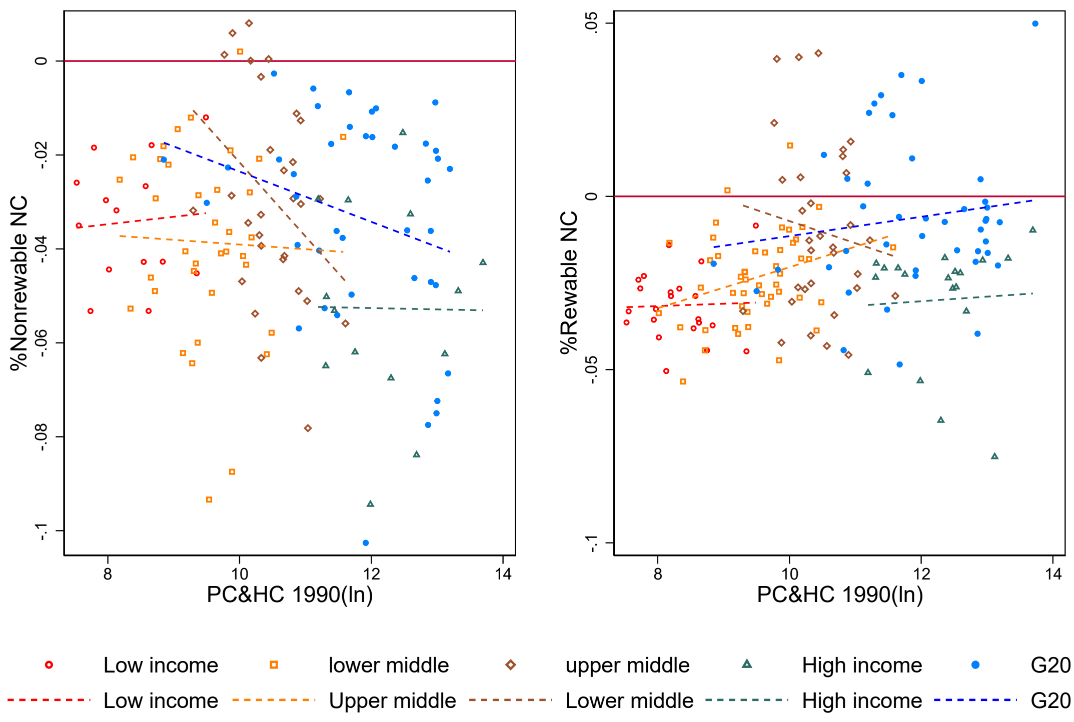

Figure 5. Degree of urbanisation vs. natural capital depletion

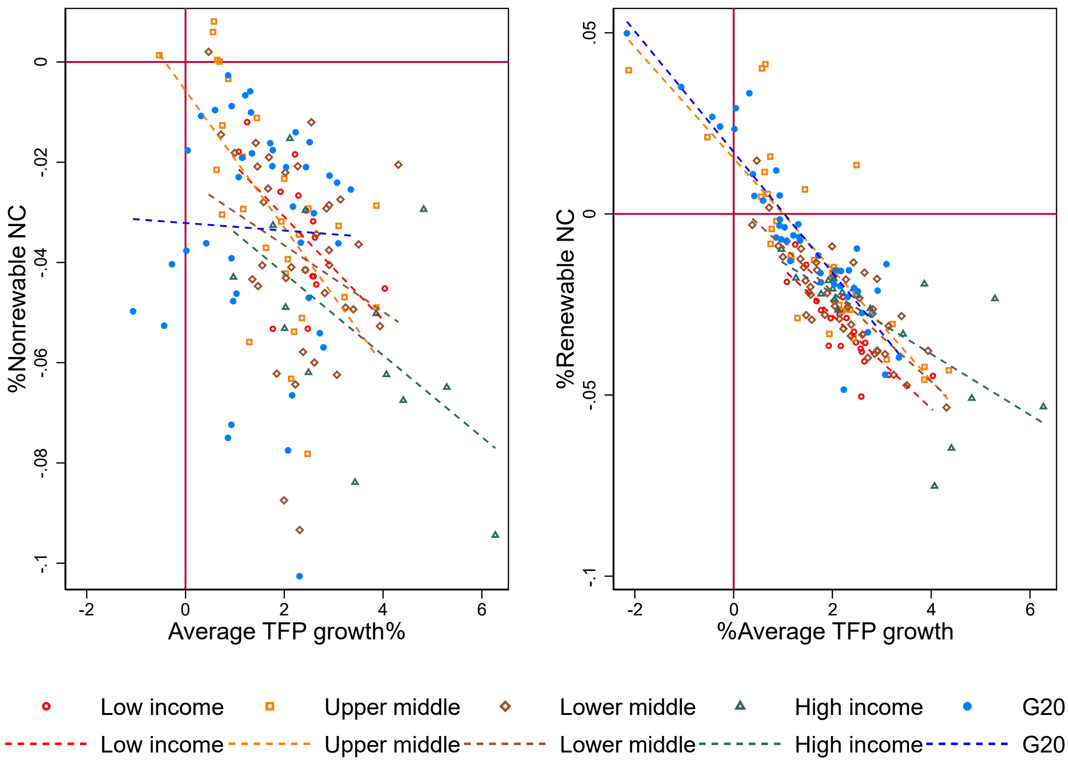

Figure 6. TFP growth inclusive of public ecossystme services vs. natural capital depletion