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Analysis

Challenges of wealth-based sustainability metrics: A critical appraisal[☆]

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ABSTRACT

There has been widespread debate about whether the way in which we measure economic activity is fit for purpose in the twenty-first century. One aspect of this debate is to move away from measuring a nation's income (GDP) towards monitoring a nation's assets (their inclusive wealth), as a better indicator of sustainable economic development. We provide the first critical comparison of the approaches of leading international organisations – the World Bank and the United Nations Environment Programme (UNEP) – to estimating changes in wealth. Our paper reveals important inconsistencies in how these organisations measure sustainability and the conflicting messages that policy makers receive, despite a common underlying conceptual framework linking changes in a nation's wealth to future well-being. We attribute these differences to methodological (applied theory) choices made by researchers at the respective institutions. These choices matter. At the most extreme, countries that perform the worst according to the UNEP are shown to perform well according to the World Bank. This confusion in signals makes better policy making more difficult.

1. Introduction

Over the past 50 years, there have been increasing debates surrounding the environmental impact of economic growth and its long-term sustainability (e.g. Nordhaus and Tobin (1973), Solow (1974), Dasgupta and Heal (1974), Solow (1993), Fleurbaey and Blanchet (2013) and Stiglitz et al. (2009)).[1] This has led to efforts to change how economic progress should be measured and the implications of increasing economic output for future well-being; for example, see a recent editorial in Nature (2023) on the topic.[2]

There is a growing consensus towards a move away from thinking about growth of Gross Domestic Product (GDP) and instead to focus attention on managing national *wealth* (Polasky et al., 2015; Clark and Harley, 2020).[3] For example, the 2021 *Dasgupta Review on the Economics of Biodiversity* argues, 'in order to judge whether the path of economic development we choose to follow is sustainable, nations need to adopt a system of economic accounts that records an inclusive measure of their wealth'. UNEP (2018b) follow this approach, arguing that measuring inclusive wealth can be used as a policy tool to assess if countries 'are developing in a way that allows future generations to meet their own needs'. The World Bank also adheres to this view and in its latest *Changing Wealth of Nations (CWON)* report argues that focusing on the change in wealth per capita could help manage risk and uncertainty, especially in the light of climate change (World Bank, 2021).

This wealth perspective is supported by a well established theoretical framework in the context of measuring wealth for sustainable development (Dasgupta, 2014; Hanley et al., 2015a) - see Appendix A1 for a brief overview. Wealth, referred to as either 'Comprehensive' or 'Inclusive', includes all assets from which people obtain well-being over time, either directly or indirectly (Dasgupta, 2001), thus wealth measures the value of all forms of capital (produced, natural, human,

☆ We would like to dedicate this article to the memory of Kirk Hamilton (1951-2024), a gentleman, scholar, and a pioneer in the field of wealth accounting.
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[1] Also, see critiques of economic growth: Meadows et al. (1972), Rockström et al. (2009), Dearing et al. (2014), IPCC (2022).
[2] Fleurbaey and Blanchet (2013) give a summary of various initiatives to go 'beyond GDP' over the years
[3] The change in wealth and net national product are closely related, for example see Arrow et al. (2003) and Sefton and Weale (2006).
[4] The CWON approach follows earlier work by Kirk Hamilton and co-authors on empirical estimates of sustainability (Hamilton, 1994; World Bank, 1997; Hamilton and Clemens, 1999). These were first empirical estimates of adjusted net saving and then later estimates of wealth. In effect, these started as empirical applications and later linked with theory. IWR by contrast started from theory and then was later applied to measurement (Arrow et al., 2004, 2012).

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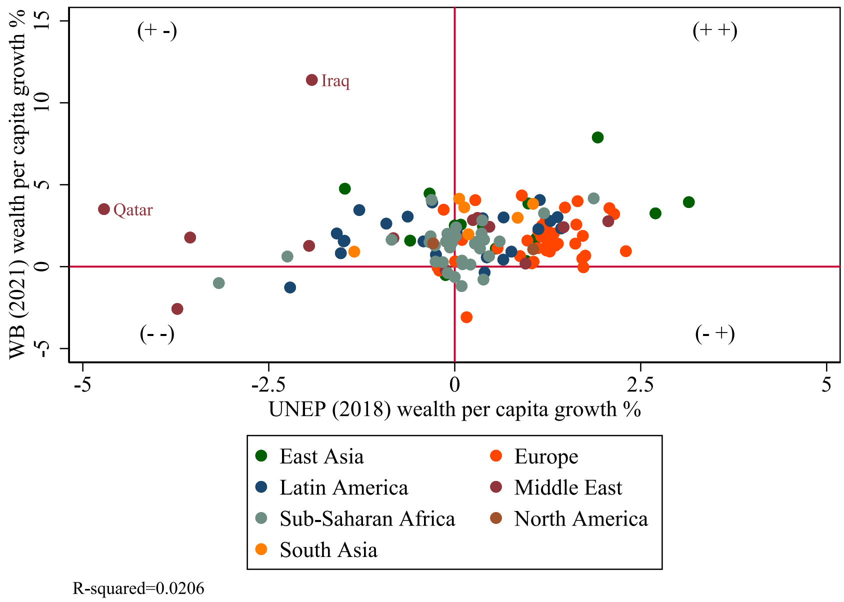

Fig. 1. Growth in Wealth per capita
Note: World Bank (2021) reports wealth data for 146 countries from 1995–2018. UNEP (2018b) reports wealth data for 140 countries from 1990–2014. Only 128 countries are reported in both WB and UNEP data, only these data are presented here and only for a comparable period of time (1995–2014)
Source: World Bank (2021), UNEP (2018b,a).

and social) in a country.[4] As shown by, for example, Arrow et al. (2012), changes in inclusive or comprehensive wealth are proportional to the future change in welfare: a positive growth of wealth (per capita) is a necessary condition for sustainable development (see also (Fenichel and Abbott, 2014; Yun et al., 2017)).

Wealth estimates have been produced by major international organisations, namely the World Bank (2006, 2011, 2018, 2021) and the UN Environmental Programme (UNU-IHDP and UNEP, 2012, 2014; UNEP, 2018b). Both the UNEP and World Bank wealth based approaches are explicitly intended to be used to monitor sustainability. For the UNEP, this means that wealth can 'provide insights into whether current growth is sustainable' (UNEP, 2018b, p. 42),[5] similarly the World Bank sees wealth as a way to 'to measure and assess the sustainability of economic development'.

In this note we highlight the pioneering empirical work of both the World Bank and the UNEP but we call for an increased dialogue and reflection on how to measure wealth. What is important is the signal that policymakers get from the *change* in wealth, not the measurement of wealth itself. We highlight how empirical estimates of changes in wealth have led to ambiguous sustainability signals and thus a potential diminution of the policy impacts of such signals.

Despite sharing the same theoretical root, the signals about sustainability that countries get from the *application* of wealth concepts by the World Bank and by UNEP are misaligned (as shown in Fig. 1).[6] According to the World Bank (2021), over the last 30 years 20 out of 146 countries have experienced negative changes in wealth per person, whereas the UNEP (2018b)'s approach estimates that 45 out of 140 countries experienced negative change in wealth per person.[7] Table 1 shows a comparison of both World Bank and UNEP estimates across a comparable time period (1995–2014); in that period 17 countries on the World Bank list are reported as negative while the UNEP reports 44 as negative. Moreover, there is little cross-over in terms of which specific countries that show unsustainable paths on this basis (see Fig. 1); only 9 of the 45 countries experiencing negative growth in wealth in the (UNEP, 2018b) list are in the World Bank (2021) list of unsustainable countries. Not only are the countries different, the signals are quite divergent. For example, the country with the highest negative growth (−4.72 percent per annum) in wealth according to UNEP is Qatar, but judging by the World Bank Qatar's per capita wealth grew by a respectable 3.51 percent per annum. Overall, there are 34 countries that report positive growth in wealth according to World Bank estimates but negative growth according to the UNEP estimates. While there are only 5 countries that experience positive growth in wealth according to UNEP estimates and negative growth according to World Bank estimates.[8]

The World Bank has deemed that *CWON* reports will be 'regular publication that will be updated repeatedly' (World Bank, 2021, p.49). Similarly, the latest (UNEP, 2022) report notes that, 'the World Bank, the OECD and the World Economic Forum agree. Decision-makers must focus on increasing wealth, and not simply GDP, if they want to ensure well-being in the 21st century'.[10] Our note shows that while these bodies may agree in principle, the empirical application differs

[5] A similar motive is given in UNEP (2023), in that 'provides policymakers with essential knowledge for making informed decisions towards sustainable economic development'.

[6] The mean difference between World Bank and UNEP estimates of the growth in wealth per capita is 1.153 percentage points (standard deviation of 2.02); at the extremes it is −3.25 percentage points and 13.32 percentage points.

[7] The World Bank period of reference is 1995–2018, while the UNEP period of reference is 1990–2014.

[8] There are also several countries clustered around 0 in Fig. 1. World Bank data shows 21 countries that range between −0.5 % and 0.5%, with a mean of 0.136%, a minimum of −0.391% and a maximum of 0.494%. While UNEP data shows 28 countries range between −0.5% and 0.5%, with a mean of −0.147% and a minimum of −0.420% and maximum of 0.025%. However, the overlap between the two estimates are very low and there are only 6 countries in both World Bank and UNEP estimates are between −0.5% and 0.5%.[9] Given the clustering around 0, this could indicate that the estimates of wealth are not sufficiently precise for us to make any comparison.

[9] These are Bahrain (−0.204%, −0.122%), Central African Republic (0.307%, −0.257%), Cote D'Ivoire (0.272%, −0.160%), Iceland (−0.048%, −0.232%), Niger (−0.391%, −0.095%), and Ukraine (0.320%, 0.004%)

[10] We are not comparing the UNEP (2023) with World Bank (2021) because the UNEP (2023) has not provided an open database that is required for such an analysis.

Table 1
Distinction between Wealth (Comprehensive & Inclusive) and change in wealth (Genuine Savings).
Source: World Bank (2021), UNEP (2018b), Yamaguchi et al. (2019), Hamilton and Clemens (1999), Bolt et al. (2002).

	Comprehensive W (World bank)	Inclusive W (UNEP)	GS (Δ W)
K_P [ΔK_P]	perpetual inventory method (machinery, buildings, equipment, intangible wealth & mineral exploration, urban land)	perpetual inventory method (machinery, buildings equipment, intangible wealth & mineral exploration)	Gross savings minus depreciation
K_N [ΔK_N]	**Nonrenewables**		
	Discounted Earnings (fossil fuels & minerals)	Stock * Shadow Price (fossil fuels & minerals)	Resource rents (fossil fuels & minerals; only depletion, not discoveries)
	Renewables		
	stock * shadow price of the wealth, constant (timber, agricultural land protected areas, mangroves & marine fisheries)	stock * shadow price (timber, agricultural land)	price * extraction (only depletion not net natural growth)
K_H [ΔK_H]:	Discounted value of life time earnings of the working population	Based on returns to education, using population educational attainment	Current spending on education
Net_{FA}	Sum of external assets & liabilities	–	Included in Gross savings
Pollution damages	Direct(excluded) Indirect (depreciation of produced & natural capital)	Direct (Carbon damages) Indirect (depreciation of produced & natural capital)	Particulate damage & CO2 emissions
Adjustments to $\Delta W/\Delta w$		Total Factor Productivity Carbon damage Oil Capital Gains	

significantly, producing confusing signals for policy makers. The fact that there is ambiguity and uncertainty between the estimates produced by the World Bank and the UNEP means that policymakers can, and will, overlook wealth estimates, perhaps viewed as still being in an experimental phase, in favour of existing metrics, thus jeopardising future sustainability.

While it is known that there are two major international organisations providing estimates of wealth, we find limited evidence of open dialogue, in terms of cross-citation,[11] between both the respective research groups behind the wealth accounts at both the World Bank and UNEP.[12] For example, Damania et al. (2023), in one of the most recent additions to the World Bank's environment and sustainable development series, states that the *CWON* 'demonstrate that natural capital is in decline' and this provides motivation for the development of new economy–environment models, yet the disparity between estimates of natural capital from the *CWON* and the UNEP (2018b) is omitted in this discussion. While Managi et al. (2024) highlight the UNEP inclusive wealth project, arguing that 'policymakers can use this information to make capital investments in their economies', they only refer to the work of the World Bank (2021) in passing and do not critically discuss the conflicting information provided by the UNEP and World Bank measures of wealth. Similarly, Yamaguchi et al. (2022), some of the authors of the UNEP (2018b), do not comment on or explain differences between the *CWON* and the UNEP (2018b) report. As we document in Fig. 1 there is no clear cut signal emerging from the work of either institution.

We are sympathetic to the efforts to measure wealth and we intend this critique to highlight the differences so that progress can be made in this area.[13] The major message from our study is the need for an agreement to standardise and harmonise wealth accounting, in a similar vein to what is done for national income (i.e., (UN SNA, 2009)) and for reporting bodies to adhere to a standardised accounting framework.[14]

While there are agreed international standards for measuring GDP, and agreed international standards for measuring natural capital (e.g., the UN System of Environmental–Economic Accounts (UN, 2014)), there is no international convention on how to measure or report wealth-based indicators of sustainable development and national economic performance. We echo calls for further and consistent incorporation of SEEA accounts into wealth measurements to narrow the gap between the competing different measures of wealth (Hamilton, 2016).

[11] Both groups are clearly aware of the other and there has likely been closed dialogue that we as academic researchers are not privy to.

[12] There has been relatively little academic engagement with the latest CWON project, with only 42 cites as of February 2024 for CWON 2021, the 2018 CWON is cited 619 times, and the 2011 CWON is cited 83 times, and the 2006 WON is cited 179 times. The 2018 IWR is cited 25 times, the 2014 Inclusive Nations report is cited 30 times, the 2012 Inclusive Wealth report is cited 1782 times [Citation data from Google Scholar, February 2024]. Recent work that uses the CWON data includes (Bastien-Olvera and Moore, 2021) and recent work that uses the IWR data includes Dasgupta et al. (2022), Managi et al. (2024); although the latter are self-citations from the research teams behind the IWR estimates. In terms of policy papers, van Zyl and Au (2018), New Zealand Treasury (2022) both cite the IWR reports.

[13] Moreover, we do not agree with Roman and Thiry (2016) that the limitations of the measures undermine their capacity to fulfil the capacity of a sustainability indicator.

[14] Here we follow an earlier comparison of the two approaches that also echoes calls for standardisation (Hamilton, 2012).

2. Measuring wealth and the change in wealth in practice

While there are strong theoretical foundations underpinning the wealth concepts,[15] these assume comprehensive coverage of capital goods and complete national income accounting (Weitzman, 2003, p. 211–212). These assumptions are tested in the real world, where approximating idealised views of capital is more complicated.

The World Bank has been at the vanguard in the push for a shift in focus from national income to national wealth and has published influential reports on the *Wealth of Nations* since 2006 (World Bank, 2006, 2011, 2018, 2021). The *CWON 2021* report estimates wealth (W), *changes* in wealth (ΔW), and changes in wealth per capita (Δw), for 146 countries over the period 1995 to 2018 (World Bank, 2021). World Bank (2018, 2021) do not include a formal mathematical definition of wealth but instead both state that: " *Wealth = renewable natural capital + nonrenewable natural capital + produced capital + human capital + net foreign assets*"[16]

The UNEP is another pioneer in the development of wealth accounts. The UNEP has published these estimates since 2012 (UNU-IHDP and UNEP, 2012, 2014; UNEP, 2018b), with a recently updated version released at the end of 2023 (UNEP, 2023). The coverage of UNEP (2018b,a) provide estimates of wealth from 1990 to 2014. UNEP draw explicitly on the wealth framework of Dasgupta (2001) and reproduce equations derived by Arrow et al. (2004) and Dasgupta (2001) (UNEP, 2018b, p.3).[17] There is some deviation from the equations in Dasgupta (2001), as market prices are used to construct accounting prices (also known as shadow prices) in practice, what Smulders (2012) referred to the 'Achilles heel' of the Arrow et al. (2012) approach to measuring wealth.

Before the World Bank began focusing explicitly on wealth estimates it had placed emphasis on a metric that proxied the change in wealth, known as Adjusted Net Savings or 'Genuine Savings'(GS).[18] Estimates of GS have been published in the *World Development Indicators* since 1997 (World Bank, 1997) and World Bank estimates for GS have been made as far back as the 1970s for some countries (Hamilton and Clemens, 1999). The World Bank continues to provide estimates of Adjusted Net Savings.[19]

The main methodological differences between the UNEP and World Bank measures of W and the World Bank's measure of GS, are highlighted in Table 1. The conceptual distinction between W and GS is that W measures the aggregate stock of wealth and GS ((1) in Appendix A1) measures changes in wealth, but not wealth directly. In terms of reproducible capital (K_P), the stock of capital represents the accumulated value of all investment in produced capital minus depreciation; which is similar to net savings (gross savings minus depreciation) in GS. World Bank also includes Urban Land in K_P and it is assumed to be a fixed 24% of produced capital.

For Natural Capital (K_N), the distinction primarily relates not so much to what elements of K_N are measured but *how* they are valued.

Table 2
Assets included in Natural Capital.

	UNEP	World Bank
Non-renewable Natural Capital		
Fossil Fuels	Oil Natural gas Coal	
Minerals	Bauxite Copper Gold Iron Ore Lead Nickel Phosphate Silver Tin Zinc	
Renewable Natural Capital		
Agricultural Land	Cropland Pasture Land	
Fisheries	Marine Fisheries –	 Mangroves
Forest resources	Timber Non-timber forest products –	 – Ecosystem Services
Protected Areas	–	Protected Areas

The monetary valuation of K_N is based on the discounted stream of expected future earnings (World Bank, 2021, p. 46), this is done directly for commercial K_N and indirectly for non-monetised (or rather non-traded) forms of K_N such as some ecosystem services. The UNEP (2018c) approach is to use fixed shadow prices (based on average shadow prices over the period of the measure). It is stated that fixing shadow prices is so that the 'focus on the quantity of change in inclusive wealth' (UNEP, 2018c, p.6). The unit shadow price of non-renewables is effectively the average rental price (market price minus private cost) (UNEP, 2018c, p.11).However, from a theoretical perspective, what matters to sustainability is non-declining real wealth per capita using a suitable divisia price index (Asheim et al., 2003).

Table 2 illustrates that non-renewable natural capital components are identical but there are some distinctions in terms of renewable natural capital. The primary difference between the World Bank and UNEP measures of K_N, in terms of what is included, relate to renewable natural capital. In forest resources, both UNEP & World Bank include timber. The UNEP also counts 'non-timber forest products' but this is not further elaborated upon. World Bank includes ecosystem services, as well as a distinct category for protected areas. While it is likely that these may be the similar to 'non-timber forest products' it is unclear from the surface whether this is true or not. Mangroves are included in WB but this is counted within fisheries (referred to as 'Blue Natural Capital'). GS by contrast only focuses on commercial aspects of ΔK_N and does not take into account resource discovery (nonrenewables) or net natural growth (renewables), this is done to maintain consistency with UN SNA (2009).[20]

Conceptually, K_H is very similar in both as it as an attempt to value the education and skills of the population. The World Bank approach measures K_H using discounted life time earnings of the working population (World Bank, 2021, p. 439). The UNEP approach is to value the returns to education; however, within this there is

[15] See Appendix A1 for an outline of the theory.

[16] The main distinction between the World Bank's earlier work (World Bank, 2006, 2011) and its recent work (World Bank, 2018, 2021) is a methodological change in how total wealth was constructed. In the former reports wealth was estimated using a top down approach based on discounted value of consumption (World Bank, 2006, 2011), in the latter it is based on the aggregation of capital stocks in purchasing power parity (PPP) dollars (World Bank, 2018, 2021). In the latest *CWON* there are additions to what is measured in natural capital and these are retrospectively included in measures of natural capital back to 1995.

[17] Duraiappah and Muñoz (2012) discuss the benefits of the Arrow et al. (2012) methodology although they highlight challenges in making the framework operational.

[18] Although it may also be referred to as "Genuine Investment" as in Arrow et al. (2004).

[19] Adjusted Net Savings are reported in World Development Indicators, with the latest available data for 2021 [Accessed February 2024].

[20] As Hamilton and Clemens (1999) state 'The [GS] calculations presented here necessarily trade off some amount of accuracy against wider coverage. Data availability limits the adjustment to savings measures to the following: valuing resource rents for nonrenewable resources, valuing depletion of forests beyond replacement levels, and valuing the marginal social costs of carbon dioxide'.

Table 3
Comparison of data coverage.
Source: UNEP (2018a), World Bank (2021, 2022b). Income groups and region classification derived from World Bank (2022a).

	Δw		
	UNEP (2018)	WB (2021)	GS
	Number of countries		
Time coverage	1995–2014	1995–2014	1995–2014
Number of countries	140	146	156
	Income group		
Low	18	20	20
Lower-middle	39	42	48
Upper-Middle	35	39	40
High (non-OECD)	14	13	14
High (OECD)	34	32	34
	Region		
East Asia & Pacific	17	15	21
Europe & Central Asia	40	44	45
Latin America & Caribbean	25	24	24
Sub-Saharan Africa	33	38	40
Middle East & North Africa	16	17	17
North America	2	2	2
South Asia	7	6	7
	ΔW <0 (Reference period: 1995–2014)		
Total number of countries	7	4	37
	Δw <0 (Reference period: 1995–2014)		
Total number of countries	44	17	–

Note: The comparisons are of benchmark estimates of W & w (UNEP, 2018a; World Bank, 2021) and do not include the adjustments outlined in Table 1.

Table 4
Correlation between indicators of change of wealth (World Bank & UNEP).

	Δw (WB) & Δw (UNEP)	Δw(UNEP) & GS	Δw (WB) & GS
Overall values	0.144	0.077	0.342
	Geographic Region		
East Asia & Pacific	0.236	0.655	0.295
Europe	0.241	0.358	−0.044
Latin America	0.304	0.277	0.244
Sub-Saharan Africa	0.424	0.185	0.409
Middle East	−0.003	−0.693	0.412
North America	–	–	–
South Asia	0.709	0.791	0.543
	Income group		
Low	0.437	0.226	0.472
Lower middle	0.020	0.058	0.425
Upper middle	0.108	0.324	0.284
High	0.233	−0.341	0.227

also an estimate of the present value of lifetime income making these approaches appear quite similar (UNEP, 2018c, p.10). While in *GS* the ΔK_H is proxied by current education spending. The primary motive for including education expenditure is that it is measured in $ terms and can thus be included (World Bank, 1995; Bolt et al., 2002).[21]

Pollution is treated differently in both. In the World Bank and UNEP estimates of W it is included indirectly in terms of the impact it has on the depreciation of the various forms of capital. UNEP (2018b) also include carbon damages as an adjustment to the benchmark ΔW estimate, however the indirect impact that climate change has on the various forms of capital run the risk that UNEP (2018b) is double counting carbon damages. In *GS* both particulate damage and CO_2 damages are included, the former through health impacts. Given the ongoing climate crisis (IPCC, 2021), motivation for the inclusion of pollution more explicitly is compelling. Here both W and *GS* overlook recent advances in the academic literature. For example, McGrath et al. (2021) show how World Bank *GS* estimates are very sensitive to the inclusion of pollutants and this inclusion places many countries on unsustainable growth paths. Likewise, Pezzey and Burke (2014) show how changing the price of CO_2 can align global *GS* with ecological indicators. However, given the size of pollution adjustments it could be argued that more could be done to incorporate pollution in wealth accounting (Muller et al., 2011), particularly as better accounting can highlight growth from the reduction in pollution activities (Muller, 2014).

Finally, only the UNEP estimates of W adjust the benchmark estimates to includes a measure of technological change.[22] The theoretical literature deems technological progress to be an integral aspect of sustainability (Weitzman, 1997, 1999). Moreover, empirical studies attribute the poor predictive capabilities of the *GS* metric for high-income countries to the absence of a measure of technological progress (Ferreira and Vincent, 2005). Other estimates of W and *GS* do incorporate measures of technological progress (Pezzey et al., 2006; Greasley et al., 2014; McLaughlin et al., 2014; Mota and Cunha-e-Sá, 2019). Therefore, the absence of technological progress is an important omission in both the World Bank's estimates of W and *GS*.

3. Comparing measurement

The comparison of the change in wealth per capita (Δw) from both the World Bank and the UNEP, as well as *GS* is shown in Tables 3 and 4.[23] The coverage of Δw from the UNEP and World Bank differs, the former begins in 1990 and ends in 2014, while the latter starts in 1995 and ends in 2018. So, while combined, they provide estimates of wealth from 1990 to 2018, they only overlap for a shorter window of time (1995 to 2014).[24] Thus, any comparison of the metrics must focus on this overlapping window. In terms of data availability, the coverage over time is one current advantage of *GS* as World Bank estimates extend back to 1970 for most countries (Hamilton and Clemens, 1999).[25]

The signal from ΔW also differs from *GS*. Only 4 countries experienced negative ΔW and 20 countries experienced negative Δw,

[21] While it may be argued that the focus on education spending is a production side focus. This rationale is not articulated in the pioneering studies (Hamilton, 1994; Hamilton and Clemens, 1999). There is a note to outline the argument that 'investing in human capital is a type of endogenous technical progress' and the view expressed in Hamilton and Clemens (1999) was that the stock of human capital was augmented through the educational system and that only capital spending from educational spending was included in the measure. It was later observed that educational expenditure may be a poor proxy for human capital formation as it does not incorporate private educational expenditure, it is a gross investment (World Bank, 2006, p.74).

[22] Arrow et al. (2012) view the level of TFP as 'another capital asset', this view is not explicitly stated in the UNEP (2018c) but the recommended procedure was, 'merely to add TFP growth to comprehensive investment' (p. 27) (or as was stated, 'we need only to add TFP growth rate to the inclusive growth rate' (p. 7)).

[23] The comparisons are of benchmark estimates and do not include the adjustments made in UNEP (2018b).

[24] There are also three historical estimates of comprehensive wealth. These are for Britain from 1760 to 2000 (McLaughlin et al., 2014), an estimate for Sweden from 1850 to 2010 (Lindmark and Andersson, 2016), and an estimate for India from 1975 to 2013 (Agarwal and Sawhney, 2021). Although, only McLaughlin et al. (2014) is a comparison of the UNU-IHDP and UNEP (2012) and World Bank (2011) methodologies.

[25] In fact, recent research has extended these measures as far back as the 1750s for Britain and the 1800s for other countries using comparable data (Rubio, 2004; Lindmark and Acar, 2013; Greasley et al., 2014; Hanley et al., 2015b; Blum et al., 2017; McLaughlin et al., 2023).

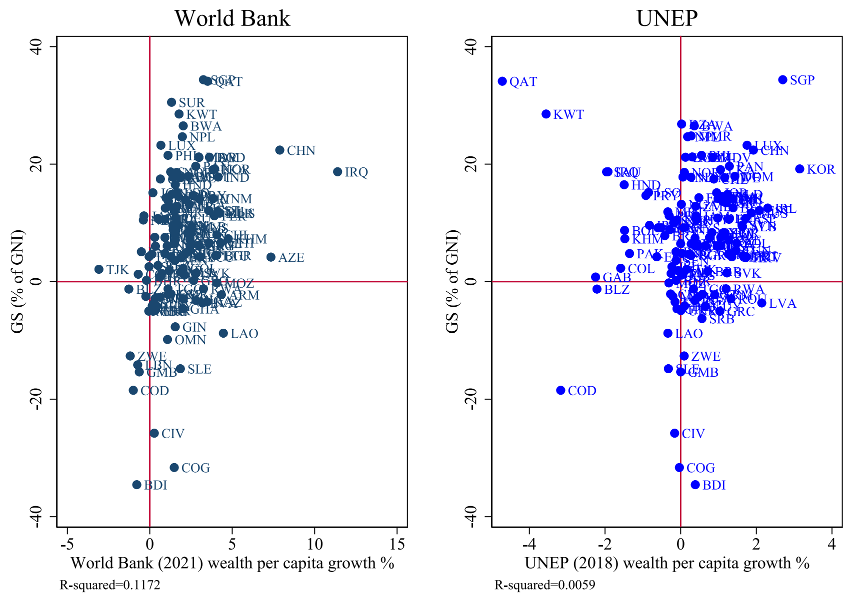

Fig. 2. Change in wealth and Genuine Savings.

primarily driven by high population growth. On the contrary, *GS* signals an unsustainable path for 34 countries. This is an important distinction for policy makers — see maps in Figs. 3, 4, 5, 6. What is the message for sustainable development if during the last 23 years only four countries have decreased their W? Does this imply that the current path is sustainable? Given that all three measures are based on the same underlying theory, why are the sustainability signals so different?

Fig. 2 and Table 4 illustrate the correlation between the different measures of the Δw. They show how they vary by region and income classification. The World Bank and UNEP measures of Δw show strongest correlation in South Asia and for low income groups. GS has a higher correlation with the World Bank's measure of Δw and this is strongest in the Middle East and South Asia and for Low and Lower-middle income countries. This contrasts somewhat with the UNEP's measure of Δw which has negative correlation in the Middle East and in High income countries. Overall, it appears that there is more alignment between the two metrics produced by the World Bank (Δw & GS) than when comparing the metrics produced by the UNEP and the World Bank. Though it is important to note that GS and the change in wealth are not the same indicators (see Appendix A1). Although GS is a crucial input in wealth construction, the objective of these tables and figures is to show how the discrepancies are common between similar measurements and sources (see Fig. 7).

At a glance, the correlation coefficients appear to suggest that the natural resource dependence may be a driver of the conflicting findings. Table 5 attempts to address this by incorporating measures of resource rents in regression analyses. This exercise is done primarily to assess the direction of associations with the growth in wealth. Some countries have greater resource rents than others and the exercise is aiming to see whether there is a systematic bias against resource dependent economies.[26] The dependent variables here are the growth in Δw as measured by CWON (World Bank) and IWR (UNEP) and ΔW as measured by GS (as a % of GNI). The focus of the analysis is only on countries that are in both the respective databases of World Bank (2021) and UNEP (2018a).[27]

Table 5 first show associations between income dummies and regional dummies, these vary by WB and UNEP estimates. Income classifications are not statistically significant for either WB or UNEP estimates, but are consistently negative for GS. The coefficients for regional dummies also differ in size and significance for both World Bank and UNEP. Including resource rents (columns 2, 5, & 8) does not change this picture. Notably, gas and oil rents are consistently negative for UNEP compared with the WB estimates. GDP per capita growth is also included in these regressions (columns 3, 6, and 9) to assess the partial correlation. This is positively correlated for both World Bank and UNEP estimates.

What is informative from this exercise is how the resources measured relate to the region. Take the MENA region which has a coefficient of 0.85 for the World Bank (column 1) whereas it has a value of −1.85 (and statistically significant) according to the UNEP (column 4). This region contains Qatar, the country referred to in the introduction which had conflicting signals according to the respective estimates. Controlling for oil and gas, the coefficients are reduced significantly in both column 1 and column 5, and lose significance in column 5. The other region which has divergent sign is Latin America & the Caribbean. Here the coefficients are positive and growing in strength as controls are added according to the WB data, while for the UNEP they are negative and declining in strength. The analysis of Genuine Savings shows consistently negative coefficients for the income groups. In Table 5 (and 11) the analysis is in terms of GS as a share of GNI. However, when GS is expressed in per capita terms, see Table 12, the regional dummies lose significance and the income dummies remain significant.

While the evidence from Table 5 suggests that it is differences in how natural capital is measured that may drive differences in the growth of wealth per capita, there is still considerable geographic

[26] For example, Atkinson and Hamilton (2003) find resource dependent countries are more likely to have seen lower GDP growth as this interacted with institutional quality and macroeconomic measures, thus leading to a low rate of genuine savings. van Krevel and Peters (2024) also find institutional quality matters for genuine savings.

[27] Table 11 repeats the exercise and includes all countries available. Overall, there are no major differences in findings between the complete databases and the sub-sample of overlapping countries. However, there is a notable difference for GS when the full sample of countries is analysed, particularly for GDP growth, coal rents, and gas rents.

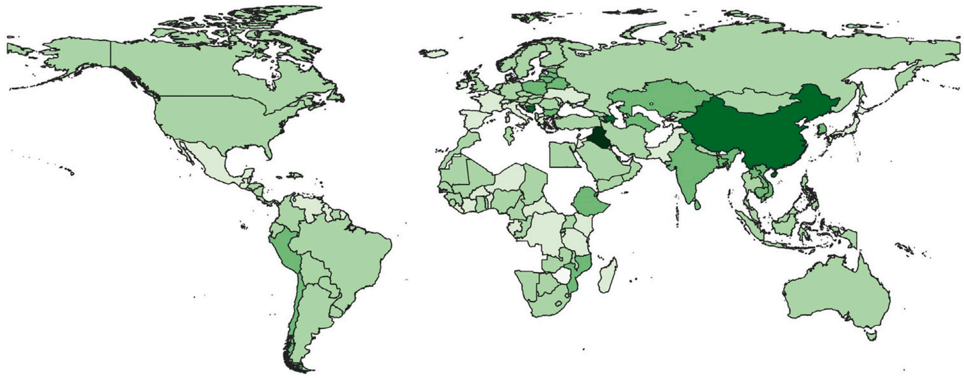

Fig. 3. World Bank wealth per capita growth, 1995–2014.

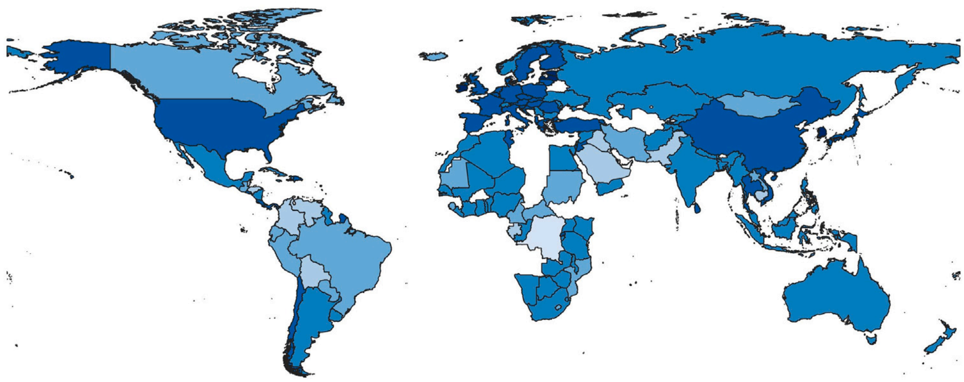

Fig. 4. UNEP wealth per capita growth, 1995–2014.

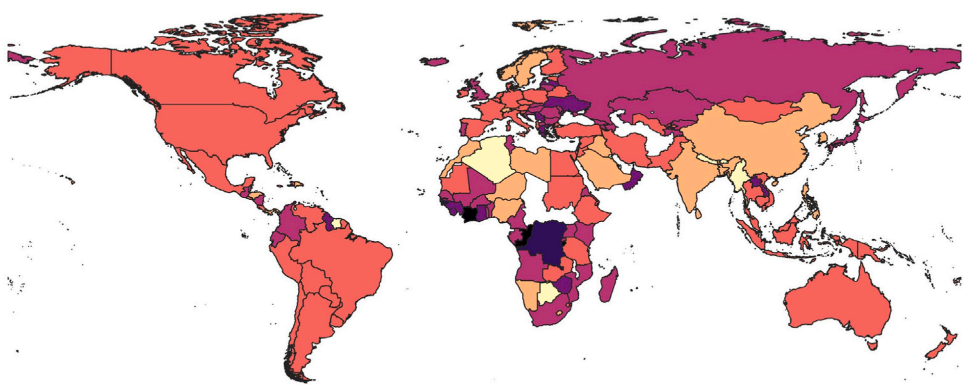

Fig. 5. GS % of GNI, 1995–2014.

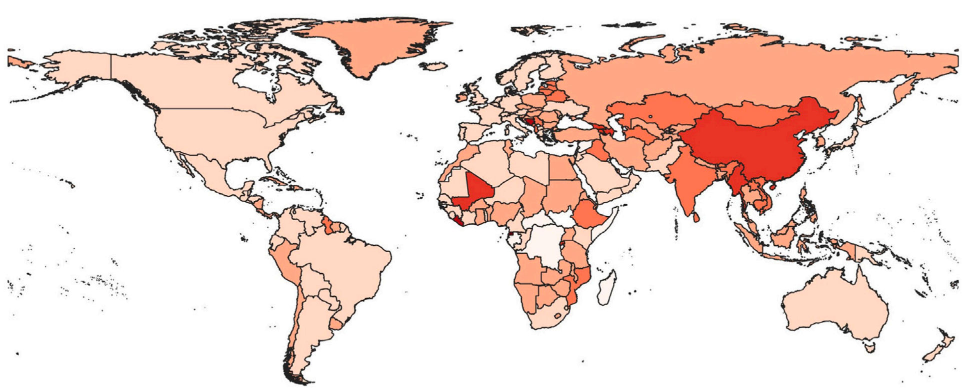

Fig. 6. GDP per capita growth, 1995–2014.

Table 5
Regression of changes in wealth, 1995–2014.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δ *w* (World Bank)			Δ *w* (UNEP)			Δ *W* (GS)		
GDP per capita %			0.61***			0.15***			0.85
			(0.115)			(0.046)			(0.531)
	Resource Rents (share of GDP)								
Minerals		−0.06	−0.11		−0.04	−0.05		−0.08	−0.12
		(0.129)	(0.104)		(0.045)	(0.045)		(0.567)	(0.617)
Coal		0.10	0.06		−0.12	−0.13		0.12	−0.00
		(0.269)	(0.235)		(0.087)	(0.092)		(1.096)	(1.185)
Oil		0.03	0.05*		−0.07***	−0.06***		−0.17	−0.16
		(0.039)	(0.027)		(0.019)	(0.018)		(0.203)	(0.203)
Gas		−0.00	−0.14		−0.39**	−0.42***		−0.00	0.05
		(0.248)	(0.152)		(0.151)	(0.155)		(1.663)	(1.573)
	Income Classification								
Low	−0.07	0.13	−0.66	−0.29	−0.61	−0.81*	−14.37**	−15.48***	−16.75***
	(0.641)	(0.705)	(0.560)	(0.503)	(0.463)	(0.472)	(5.717)	(5.892)	(6.018)
Lower Middle	−0.31	−0.22	−0.66	−0.45	−0.55*	−0.66**	−8.92***	−9.43***	−10.19***
	(0.512)	(0.561)	(0.442)	(0.396)	(0.306)	(0.287)	(2.564)	(3.002)	(2.991)
Upper Middle	0.72	0.68	−0.02	−0.34	−0.28	−0.45*	−4.34**	−4.26*	−5.37**
	(0.619)	(0.578)	(0.380)	(0.330)	(0.249)	(0.232)	(2.142)	(2.286)	(2.281)
High	Reference Group								
	Regions								
East Asia & Pacific	1.36**	1.33**	0.99**	−0.22	0.02	−0.07	9.52***	9.95***	9.50***
	(0.645)	(0.656)	(0.401)	(0.388)	(0.352)	(0.332)	(3.027)	(3.262)	(3.199)
Latin America & Caribbean	0.06	0.08	0.70*	−0.99***	−0.85***	−0.69***	5.20**	5.54**	6.59***
	(0.537)	(0.552)	(0.400)	(0.314)	(0.267)	(0.247)	(2.078)	(2.298)	(2.343)
Middle East & North Africa	0.85	0.20	0.65	−1.85***	−0.25	−0.14	12.27***	16.01***	16.39***
	(0.932)	(0.804)	(0.524)	(0.684)	(0.532)	(0.494)	(3.523)	(5.485)	(5.371)
North America	−0.25	−0.26	0.37	−0.81	−0.68*	−0.52	−0.99	−1.07	−0.30
	(0.271)	(0.298)	(0.286)	(0.511)	(0.397)	(0.393)	(1.601)	(1.884)	(1.972)
South Asia	1.56**	1.49**	1.26**	−0.60	−0.59	−0.65*	19.25***	19.50***	19.30***
	(0.704)	(0.725)	(0.509)	(0.447)	(0.367)	(0.329)	(3.109)	(3.352)	(3.178)
Sub-Saharan Africa	−0.24	−0.38	0.21	−0.86**	−0.58*	−0.44	2.67	3.72	4.78
	(0.540)	(0.608)	(0.496)	(0.378)	(0.310)	(0.309)	(3.715)	(3.724)	(3.723)
Europe & Central Asia	Reference Group								
Constant	1.49***	1.46***	0.01	1.19***	1.38***	1.02***	8.54***	8.75***	6.68***
	(0.236)	(0.241)	(0.334)	(0.125)	(0.106)	(0.151)	(1.266)	(1.303)	(1.894)
Observations	128	128	128	128	128	128	121	121	121
R-squared	0.14	0.16	0.54	0.27	0.52	0.57	0.32	0.33	0.35
Mean		1.829%			0.292%			7.999 (% of GNI)	
Standard Deviation		1.777%			1.249%			10.887 (% of GNI)	

Note: Only countries that are in both the CWON and IWR database are included in these regressions. The estimates of *w* do not include any of the adjustments outlined in Table 1. Robust standard errors in parentheses.
*** $p<0.01$.
** $p<0.05$.
* $p<0.1$

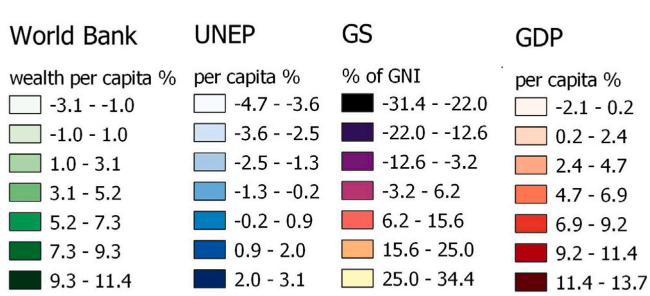

Fig. 7. Map legend.

variation. Oil rents in particular have differing impacts on the growth of wealth per capita in the World Bank and UNEP measures of wealth per capita, but the impacts appear to be low. While gas rents show similar signs for both, but they are larger and statistically significant for the UNEP measures. Arguably an interpretation of this pattern could be how the Hartwick Rule is manifested according to how wealth is being measured. In the WB data, resource rich countries in the region may be adhering to the Hartwick rule and reinvesting in other forms of capital, while according to the UNEP data this is not evident.

This is further explored in Fig. 8 which looks at the growth in the various types of capitals that make up wealth (e.g., as shown in Table 1). Fig. 8 purposely uses the same scales across each quadrant and includes R-squared of the capital estimates.[28] Unsurprisingly, the closest match is physical capital as both World Bank (2021) and UNEP (2018b) use the same established methodology to measure what is conventionally considered capital. The largest variation is in natural capital growth, but more problematic, given its relative size in the composition of wealth, is the measurement of human capital.[29] As shown in Table 1,

[28] The final wealth growth index is, in effect, a weighted average of the growth of each capital stock and the country specific weights depend on the share of each capital stock in a country's total wealth of a country.

[29] 'Health capital'' dominated (Arrow et al., 2012)'s estimates of wealth, whereby health capital was measured by life expectancy and the value of a statistical life. This approach was heavily criticised (e.g. see Hamilton (2012),

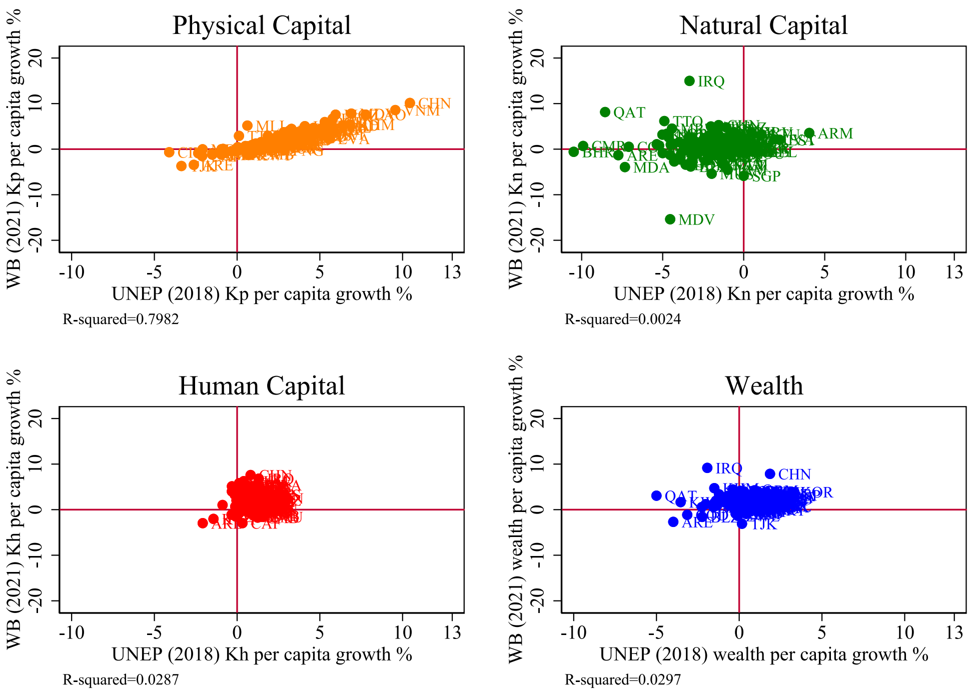

Fig. 8. Comparing the Components.

this difference reflects different methodological approaches to valuing human capital, one based on discounted life times earnings and another on returns to education.

Table 6 repeats the analysis of Table 5 on the change in Natural Capital. Here we see notable distinctions in terms of the regional dummies. Particularly the persistent negative coefficients for the MENA, South Asia, and Sub-Saharan Africa regions for UNEP estimates but, apart from Sub-Saharan Africa, these are positive for World Bank estimates although not statistically significant. Also, the coefficient on oil rents are larger for the World Bank estimates of Natural Capital than they are for the World Banks estimates of Total Wealth (in Table 5). Whereas only gas rents are statistically significant for UNEP measures.

Table 7 repeats the analysis of Table 5 for human capital, here we see limited statistical significance for regional dummies and resource rents. Instead the Upper-Middle dummy is consistently positive for the World Bank measure (columns 1 & 2) and including GDP per capita growth (column 3) has a large positive coefficient for the World Bank measure of wealth and also improves the R-squared of the model. As natural capital and human capital are larger components of wealth in low-income and high-income countries respectively, the analysis from Tables 6 and 7 and Fig. 8 explains the difference in the underlying estimates of the change of wealth in both low- and high-income countries. The analysis is further expanded in appendices to this paper, the inconsistencies are also apparent when the measures of wealth are not measured in per capita terms (Appendix A4).

The implication of the above analysis might be that development has been sustainable, but at the cost of natural capital. This could be a reflection of an inherent bias towards "weak sustainability" in the wealth measures. By this we mean that natural capital depletion was offset by increases in other forms of wealth.[30] Fig. 9 highlights the relationship between natural capital and wealth growth in each. For the World Bank data, there are only 12 countries that have both negative growth in wealth per capita and negative growth in natural capital per capita. In contrast, the UNEP data shows 43 countries with both negative growth in both wealth per capita and natural capital. However, the majority of countries in the UNEP data show negative natural capital per capita growth which is the opposite of the signal from World Bank data, see Fig. 10.

Yamaguchi et al. (2019) compare the components of wealth in UNEP (2018a) and World Bank (2018), while they noted a convergence in methodology they also highlighted 'notable differences'. These relate to the inclusion of urban land with produced capital (World Bank), fisheries (UNEP), protected land (World Bank), net foreign assets (World Bank), and adjustments listed in 1 (UNEP). Apart from fisheries, which are now included in both UNEP & World Bank measures, these differences remain.

In the regressions reported in Table 5 we do not include the UNEP adjustments but the remaining differences may explain some of the divergences. Given that the World Bank data is publicly available, we are able to exclude the various components that are added to the World Bank measures of W, thus making it possible to assess how some of these differences contribute to the growth of wealth per capita. In Table 8 we repeat the analysis of columns 1–3 in Table 5 for estimates of Δw (World Bank) that exclude Net Foreign Assets, Protected Land, and Urban Land. It is important to stress, that while the levels of the total value of W and w may differ, this exercise is focusing on Δw and so what matters is the growth rate of the variables we exclude and their relative weight in Δw.

Net foreign assets were more volatile than W, the mean growth rate per capita was −7.03 per cent between 1995 and 2014, but again

Solow (2012)). Health capital is not included in human capital estimates in UNEP (2018b), and instead this is based the rate of return of education multiplied by the population who has education' (UNEP, 2018c, p. 10).

[30] Yun et al. (2017) show how properly measured natural capital can reflect the limitations of substitution. An issue here may be that the shadow prices of natural capital are not correctly defined. The definition used by UNEP is: "The shadow prices are essentially marginal contributions to the intertemporal well-being of an additional unit of capital in question". (UNEP, 2018c, p.6). However, in practice the UNEP uses market prices and only under special conditions do market and shadow prices coincide.

Table 6
Regressions of changes in Natural Capital per capita, 1995–2014.

	(1)	(2)	(3)	(4)	(5)	(6)
	ΔK_N (World Bank)			ΔK_N (UNEP)		
GDP per capita %			0.40**			0.26**
			(0.165)			(0.101)
	Resource Rents (share of GDP)					
Minerals		0.22	0.19		0.05	0.02
		(0.159)	(0.148)		(0.071)	(0.067)
Coal		0.53	0.51		−0.14	−0.15
		(0.403)	(0.399)		(0.149)	(0.150)
Oil		0.08	0.10*		−0.01	−0.01
		(0.056)	(0.051)		(0.015)	(0.014)
Gas		0.49	0.40		−0.65**	−0.71***
		(0.466)	(0.408)		(0.250)	(0.252)
	Income Classification					
Low	−0.90	−0.64	−1.16	0.16	−0.05	−0.38
	(1.217)	(1.265)	(1.236)	(0.732)	(0.734)	(0.709)
Lower Middle	−1.26	−1.44	−1.73*	0.48	0.38	0.20
	(1.058)	(1.048)	(0.997)	(0.513)	(0.497)	(0.481)
Upper Middle	0.12	−0.12	−0.58	0.40	0.35	0.05
	(1.186)	(1.050)	(0.979)	(0.577)	(0.572)	(0.532)
High	Reference Group					
	Regions					
East Asia & Pacific	0.39	−0.30	−0.53	−0.95*	−0.87*	−1.01**
	(1.171)	(1.146)	(1.111)	(0.496)	(0.481)	(0.494)
Latin America & Caribbean	−0.70	−0.89	−0.48	−1.39**	−1.33**	−1.07*
	(0.995)	(0.870)	(0.803)	(0.584)	(0.605)	(0.564)
Middle East & North Africa	2.29	0.38	0.68	−3.43***	−2.64***	−2.45***
	(1.555)	(1.178)	(1.090)	(0.852)	(0.814)	(0.737)
North America	0.51	0.28	0.69	−0.90**	−0.68*	−0.42
	(0.846)	(0.848)	(0.888)	(0.443)	(0.354)	(0.346)
South Asia	3.64	3.86	3.71	−2.31***	−2.26***	−2.35***
	(3.720)	(3.846)	(3.934)	(0.732)	(0.742)	(0.654)
Sub-Saharan Africa	−1.01	−1.40	−1.01	−2.18***	−2.17***	−1.92***
	(1.088)	(1.089)	(1.052)	(0.654)	(0.667)	(0.645)
Europe & Central Asia	Reference Group					
Constant	1.77**	1.48*	0.52	−1.00***	−0.79**	−1.40***
	(0.843)	(0.884)	(1.021)	(0.314)	(0.304)	(0.359)
Observations	128	128	128	128	128	128
R-squared	0.12	0.18	0.21	0.28	0.35	0.40
Mean		1.47%			−2.11%	
Standard Deviation		3.81%			2.01%	

Note: Only countries that are in both the CWON and IWR database are included in these regressions.
Robust standard errors in parentheses.
*** p<0.01.
** p<0.05.
* p<0.1

this represented a very small share of total wealth at −2.45 per cent.[31] In the case of the growth of protected areas, this was roughly treble that of natural capital as a whole and 2.5 times the growth of wealth per capita; however protected areas were, on average, 7.16 percent of natural capital and 1.33 percent of total wealth over the period 1995–2014.[32] For urban land, the World Bank assume that it was a fixed ratio of 24% of the produced capital (World Bank, 2021, p.438). As urban land is a fixed ratio, this does not affect the growth rate of produced capital, i.e. in Table 8 it would be the same as columns 4–6 as the growth rate of urban land is the same as the growth of produced capital. However, to assess whether this assumption is driving a wedge between the World Bank and UNEP estimates of the change in wealth per capita we make use of the UNEP measure of produced capital and weigh this by the produced capital share (excluding urban land) of the World Bank wealth to estimate a different growth rate of produced capital. Overall, the results are similar to columns 1–3 of Table 5. The most notable difference relates to the income classification dummies in column 9, which are now more aligned with UNEP from Table 5. Further, we illustrate how the various adjustments compare against the UNEP estimates of the Δw in Fig. 11. The adjustments are modest and a pattern similar to Fig. 1 remains. We conclude from this analysis that it is not these differences in composition of assets that are driving the divergence between World Bank and UNEP estimates of the change in wealth per capita but rather the methodology underpinning the estimates.

3.1. Growth in wealth per capita and GDP per capita

Given that wealth has been touted as an additional indicator for conventional measurement of national economy's, an important question is whether the growth in wealth per capita differs from growth in GDP per capita. Does measuring national economic performance using GDP send different signals than measuring the same performance using changes in wealth?

[31] To take the example of Qatar the growth in NFA per capita was −1.2 percent, NFA represented 21.86 percent of total wealth. Thus, without an NFA adjustment Qatar's wealth estimate would have been further away from that of the UNEP.

[32] Again, using Qatar as an example, it had a 10 percentage increase in natural capital but saw a −4.54 percent growth in protected area per capita, however protected areas were only 0.13 percent of Qatar's natural capital.

Table 7
Regressions of changes in Human Capital per capita, 1995–2014.

	(1)	(2)	(3)	(4)	(5)	(6)
	ΔK_H (World Bank)			ΔK_H (UNEP)		
GDP per capita %			0.74***			0.02
			(0.113)			(0.027)
	Resource Rents (share of GDP)					
Minerals		−0.04	−0.10		−0.03	−0.03
		(0.127)	(0.085)		(0.022)	(0.021)
Coal		0.15	0.10		−0.07	−0.07
		(0.273)	(0.172)		(0.057)	(0.055)
Oil		−0.01	0.01		−0.00	−0.00
		(0.040)	(0.025)		(0.011)	(0.011)
Gas		0.27	0.10		−0.03	−0.04
		(0.266)	(0.250)		(0.056)	(0.055)
	Income Classification					
Low	1.38	1.41	0.46	0.09	0.09	0.07
	(0.900)	(0.914)	(0.658)	(0.216)	(0.203)	(0.191)
Lower Middle	0.95*	0.95*	0.41	−0.06	−0.01	−0.03
	(0.483)	(0.512)	(0.389)	(0.164)	(0.161)	(0.150)
Upper Middle	1.65***	1.67***	0.82**	0.19	0.21	0.19
	(0.545)	(0.530)	(0.370)	(0.128)	(0.139)	(0.128)
High	Reference Group					
	Regions					
East Asia & Pacific	0.42	0.39	−0.03	0.13	0.20*	0.19*
	(0.610)	(0.634)	(0.353)	(0.116)	(0.104)	(0.110)
Latin America & Caribbean	−0.70	−0.67	0.09	−0.02	−0.01	0.01
	(0.491)	(0.512)	(0.418)	(0.102)	(0.109)	(0.102)
Middle East & North Africa	−1.16	−1.13	−0.57	−0.03	0.01	0.03
	(0.849)	(0.783)	(0.478)	(0.326)	(0.307)	(0.295)
North America	−0.78**	−0.88**	−0.12	−0.16	−0.13	−0.11
	(0.306)	(0.340)	(0.240)	(0.102)	(0.111)	(0.119)
South Asia	−0.00	−0.01	−0.29	−0.07	−0.10	−0.11
	(0.732)	(0.747)	(0.544)	(0.186)	(0.181)	(0.188)
Sub-Saharan Africa	−1.57**	−1.50**	−0.78	−0.26	−0.25*	−0.23
	(0.616)	(0.607)	(0.493)	(0.167)	(0.150)	(0.143)
Europe & Central Asia	Reference Group					
Constant	1.90***	1.82***	0.06	0.52***	0.54***	0.50***
	(0.305)	(0.319)	(0.319)	(0.052)	(0.054)	(0.098)
Observations	128	128	128	128	128	128
R-squared	0.14	0.15	0.55	0.11	0.14	0.14
Mean		2.14%			0.50%	
Standard Deviation		2.09%			0.48%	

Note: Only countries that are in both the CWON and IWR database are included in these regressions.
Robust standard errors in parentheses.
*** p<0.01.
** p<0.05.
* p<0.1

As Fig. 12 shows, we find a clear deviation in terms of the relationship between the annual growth rate of wealth from the World Bank and wealth as measured by UNEP. For the former, there is a strong positive correlation between both wealth and GDP per capita growth, while for the latter there is no clear relationship between the two. GS, both including and excluding particulate matter damages, shows a weaker correlation with GDP growth than either the World Bank or UNEP measure of the change in wealth (see Fig. 13).[33]

This is further elaborated in pairwise correlations across regions and income categories, shown in Table 9. The World Bank's measure of wealth is strongly correlated with GDP growth across all regions and all income groups. Whereas, the UNEP's wealth measure is only strongly correlated in South Asia and is highest in the Upper Middle Income and High Income countries. Table 9 also includes Genuine Savings, this too is weakly correlated with GDP growth but shows signs of strong correlation in South Asia and in the low and lower-middle income groups.

4. Discussion

We have argued above that both the World Bank and the UNEP have recognised the importance of wealth-based indicators of sustainable economic development. However, it is clear that both international organisations are reporting wealth and the change in wealth differently. We sought to understand what is driving these differences and if this is a problem.

The World Bank *CWON 2021* report argues that the change in wealth per capita is a good predictor of future sustainability. However, the sustainability signal from this metric differs significantly from the UNEP's measure of Δw and GS over the same period, which in turn offers a more optimistic view of the future than other academics.[34]

[33] It would be worth exploring this relationship over longer time-horizons however available data on wealth does not extend past 1990. However, McLaughlin et al. (2023) highlight the relationship between GDP growth and GS over 150 year time-horizon and show a gap between GDP % and GS.

[34] For example, the work of scholars emphasising 'Planetary Boundaries' (Steffen et al., 2015; Richardson et al., 2023) or the prognosis of the IPCC (2021).

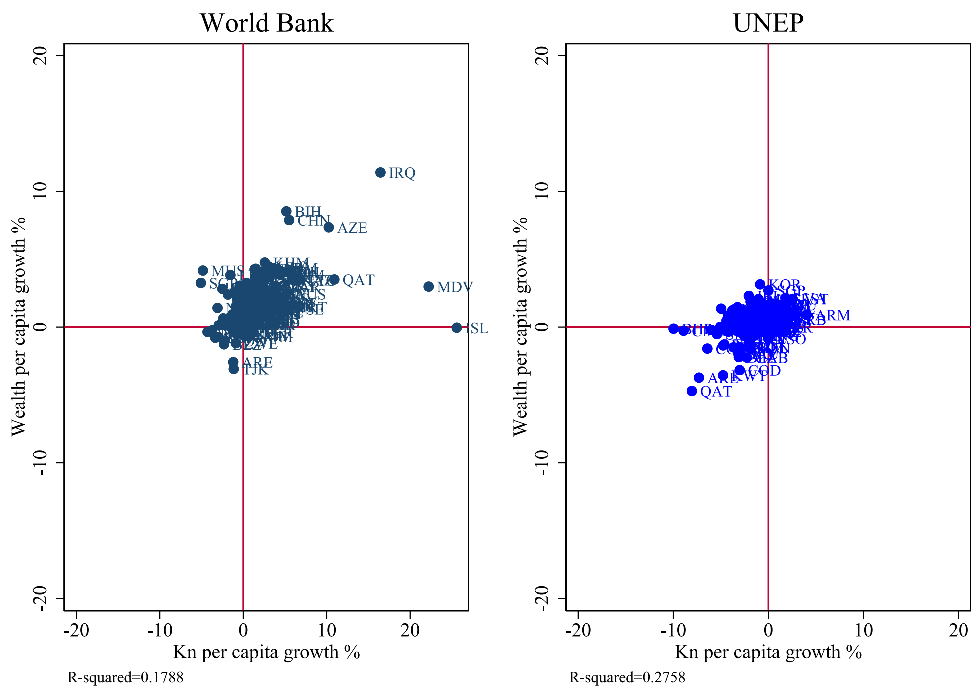

Fig. 9. Comparing Growth in Wealth per capita and Natural Capital per capita.

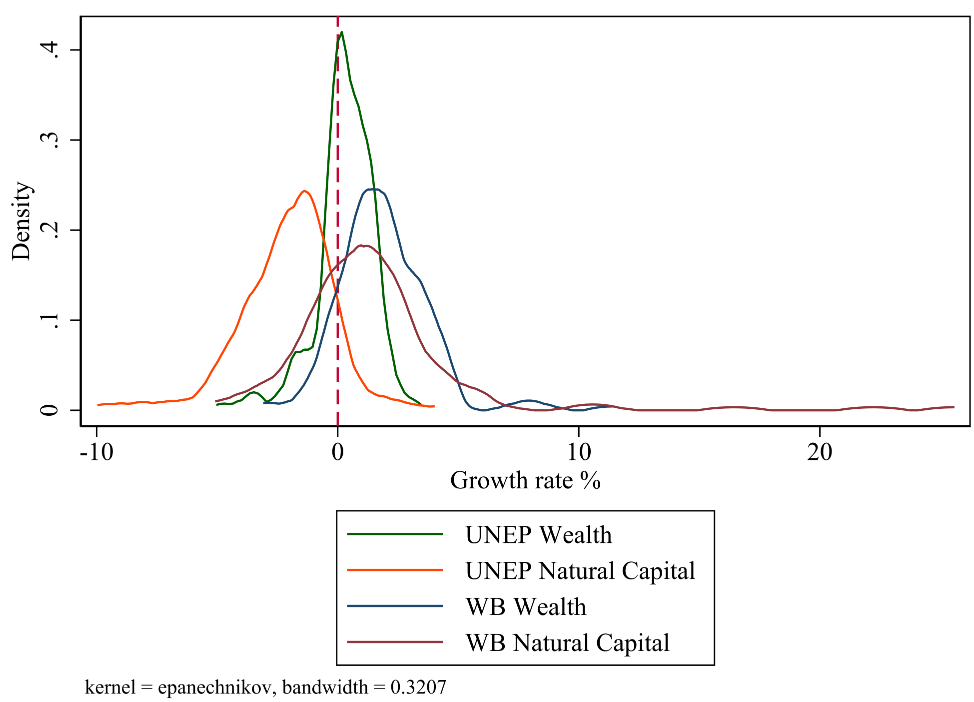

Fig. 10. Distribution of Growth in Wealth per capita and Natural Capital per capita.

Perhaps the differences in output is merely a result of the use of different sources of information. However, as these are global estimates, inevitably similar data sources will be used to derive these estimates.[35] Country specific estimates tend to be more detailed as there is access to a wider arrange of source material than is available for cross-country estimates (e.g. World Bank (2021, p.46)).[36] It could also be argued that the figures from the both the UNEP and World Bank represent a

[35] For example, both UNEP (2018c) and World Bank (2021) use FAO data to estimate forestry and US Geological Survey for various minerals.

[36] For example, some unpublished ONS estimates of Inclusive Wealth for the UK show a greater array of goods included in measuring Natural capital. There are also country specific estimates of GS that are able to incorporate resources specific to the countries in question (Hanley et al., 2015a).

Table 8
Regression of changes in wealth using different forms of World Bank (2021).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δ *w* (World Bank)								
	Excl NFA			Excl NFA & Protected			Excl NFA, Protected, & Urban		
GDP per capita %			0.59***			0.59***			0.58***
			(0.115)			(0.114)			(0.116)
	Resource Rents (share of GDP)								
Minerals		−0.05	−0.10		−0.05	−0.10		−0.03	−0.08
		(0.118)	(0.096)		(0.119)	(0.097)		(0.109)	(0.090)
Coal		0.22	0.18		0.23	0.19		0.23	0.19
		(0.246)	(0.214)		(0.246)	(0.212)		(0.234)	(0.206)
Oil		0.02	0.04		0.02	0.04*		0.02	0.04*
		(0.035)	(0.023)		(0.035)	(0.023)		(0.035)	(0.023)
Gas		0.08	−0.05		0.09	−0.04		0.07	−0.07
		(0.262)	(0.197)		(0.261)	(0.196)		(0.266)	(0.215)
	Income Classification								
Low	−0.14	0.02	−0.74	−0.21	−0.04	−0.80	−0.45	−0.30	−1.06*
	(0.643)	(0.693)	(0.548)	(0.647)	(0.697)	(0.546)	(0.653)	(0.702)	(0.557)
Lower Middle	−0.34	−0.31	−0.73	−0.35	−0.32	−0.75*	−0.53	−0.53	−0.95**
	(0.523)	(0.562)	(0.449)	(0.523)	(0.562)	(0.449)	(0.518)	(0.554)	(0.443)
Upper Middle	0.60	0.55	−0.13	0.59	0.54	−0.14	0.35	0.28	−0.39
	(0.582)	(0.555)	(0.374)	(0.581)	(0.554)	(0.371)	(0.597)	(0.565)	(0.401)
High	Reference Group								
	Regions								
East Asia & Pacific	1.22*	1.14*	0.80*	1.25*	1.17*	0.83**	1.28*	1.17*	0.84**
	(0.653)	(0.661)	(0.404)	(0.653)	(0.661)	(0.403)	(0.650)	(0.657)	(0.407)
Latin America & Caribbean	−0.06	−0.01	0.59	−0.03	0.02	0.62	−0.09	−0.05	0.55
	(0.517)	(0.528)	(0.391)	(0.518)	(0.527)	(0.390)	(0.520)	(0.527)	(0.410)
Middle East & North Africa	0.71	0.27	0.71	0.72	0.27	0.71	0.58	0.13	0.57
	(0.905)	(0.789)	(0.521)	(0.904)	(0.783)	(0.513)	(0.920)	(0.781)	(0.520)
North America	−0.40*	−0.45*	0.15	−0.40*	−0.45*	0.16	−0.38	−0.43	0.17
	(0.237)	(0.266)	(0.225)	(0.236)	(0.264)	(0.222)	(0.253)	(0.282)	(0.228)
South Asia	1.46**	1.43*	1.21**	1.49**	1.46*	1.24**	1.32*	1.31*	1.09**
	(0.714)	(0.731)	(0.521)	(0.725)	(0.742)	(0.531)	(0.745)	(0.756)	(0.544)
Sub-Saharan Africa	−0.60	−0.68	−0.11	−0.56	−0.65	−0.07	−0.62	−0.72	−0.15
	(0.534)	(0.587)	(0.486)	(0.534)	(0.588)	(0.485)	(0.548)	(0.599)	(0.495)
Europe & Central Asia	Reference Group								
Constant	1.65***	1.60***	0.19	1.63***	1.58***	0.17	1.91***	1.86***	0.46
	(0.234)	(0.241)	(0.322)	(0.233)	(0.240)	(0.321)	(0.251)	(0.259)	(0.329)
Observations	128	128	128	128	128	128	128	128	128
R-squared	0.16	0.18	0.54	0.17	0.18	0.55	0.17	0.18	0.52
Mean		1.79%			1.78%			1.87%	
Standard Deviation		1.74%			1.75%			1.77%	

Note: Only countries that are in both the CWON and IWR database are included in these regressions. The estimates of *w* exclude Net Foreign Assets in Columns 1–3, Net Foreign Assets and Protected Land in columns 4–6, and Net Foreign Assets, Protected Land, and Urban Land in columns 7–9.
Robust standard errors in parentheses.
*** p<0.01.
** p<0.05.
* p<0.1

continuum and somewhere in between represents the "true" range of sustainability.

We illustrate this in Fig. 14 by applying an upper and lower bound estimate to the baseline estimates of both the World Bank and the UNEP 10 percent error to estimates.[37] These adjustments are not sufficiently large to shift the distributions of either and there is still limited overlap between the two.

Fig. 15 represents such a range by making a compromise figure which is an unweighted average of both approaches, it also incorporates a lower and upper bound estimate based on Fig. 14. The compromise figure has a mean of 1.06%, which is equidistant from the mean of the UNEP (0.29%) and the World Bank (1.82%). Table 10 compiles a list of the countries that show negative growth rates in wealth per capita under the different metrics. There are 8 countries that are shown as negative growth in wealth per capita on each metric. There are 2 countries that have negative growth in wealth per capita according to the World Bank list but are positive as per the UNEP and the compromise estimate. There are 6 countries that are negative for both the UNEP list and the compromise list but positive on the World Bank list. There are 27 countries showing negative growth in wealth per capita according to the UNEP but are returned as positive on both the World Bank and Compromise list. Of the 43 countries listed here, the most common characteristic is high population growth and low or lower-middle income status, although these are not mutually exclusive. There are only 12 that would be classified as high resource rents, that is greater than 20% of GDP. Sub-Saharan African countries comprise 14 of the countries in the table followed by 12 countries from Latin America & the Caribbean, and 7 from the Middle East & North Africa. While some countries are small, the list contains 4 of the most populous countries in the world.[38] High population growth is a key feature of the

[37] We also applied a lower bound (5%) estimate but the differences were trivial.

[38] Brazil and Pakistan are ranked in the top ten, while Iran and the Democratic Republic of Congo are ranked in the top 20 for population size

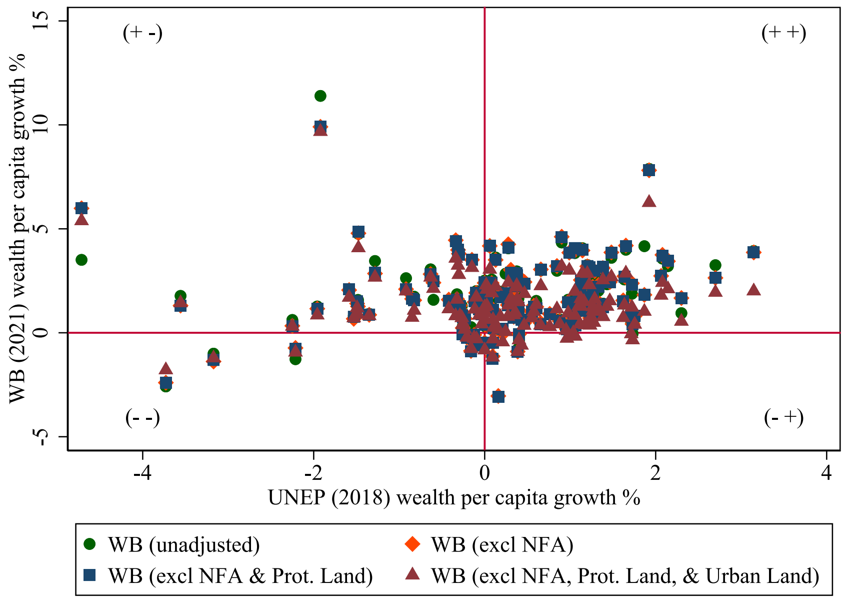

Fig. 11. Comparing Growth in Wealth per capita: World Bank adjustments and UNEP.

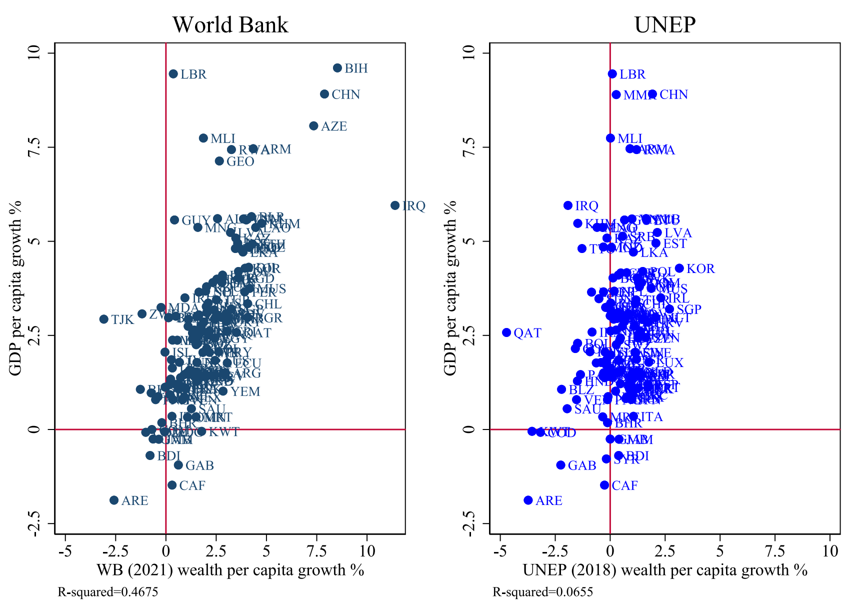

Fig. 12. Wealth per capita growth and GDP per capita growth.

countries which appear as negative across all measures of the change in wealth per capita. In the group of countries that have negative wealth per capita growth only according to the UNEP, 11 of these countries have high population growth. Focusing more on these countries can help us understand what exactly is driving these inconsistencies in the measurement of the change in wealth per capita.

The compromise figure is not satisfactory. In essence it requires that the growth rates in wealth per capita are co-trending, but what we have highlighted is that there is significant variation and a not insignificant amount of divergence between the estimates. This matters for any policy decision based on this range. To return to the example of Qatar, is wealth decreasing at a rate of −4.72% per annum or growing by 3.51% per annum, or somewhere in between (−0.61%)? If it is the former, some remedial action is required to return Qatar to a sustainable path, if it is the latter such remedial action could undermine this growth in wealth and unnecessarily harm future well-being, whilst somewhere in between still requires some remedial action. The answer is simply that we do not know given these current estimates.

While the World Bank efforts are admirable for collating data for 146 countries there is an element of superficiality to this exercise. As Lange and Naikal note 'given the need to harmonise data across countries, the wealth accounts for any country are unlikely to be as accurate as the accounts that the country might construct itself using its own, more accurate and comprehensive data sources' (World Bank, 2021, p.46). Therefore, future work is needed to create an agreed set of definitions of what should/should not be included in such wealth accounts in order for countries to build upon this body of work.

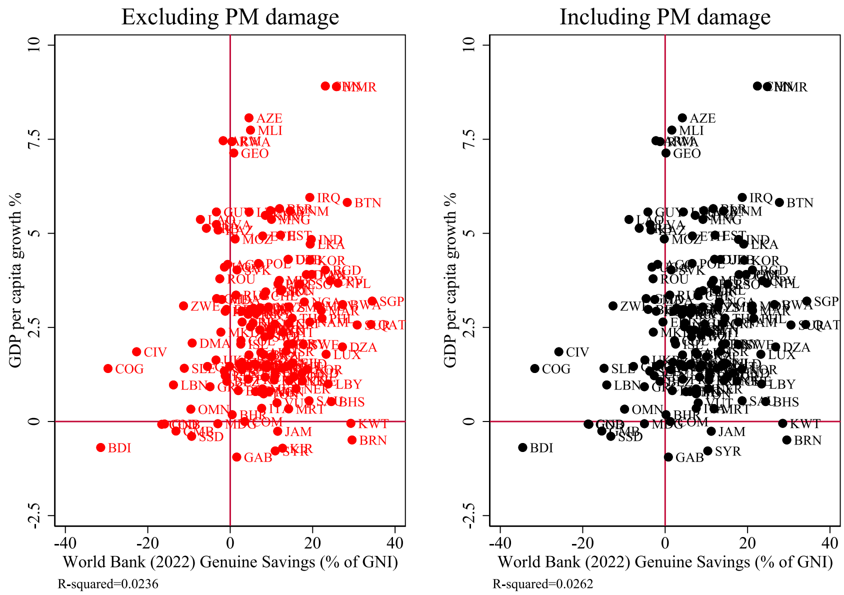

Fig. 13. Genuine Savings and GDP per capita growth.

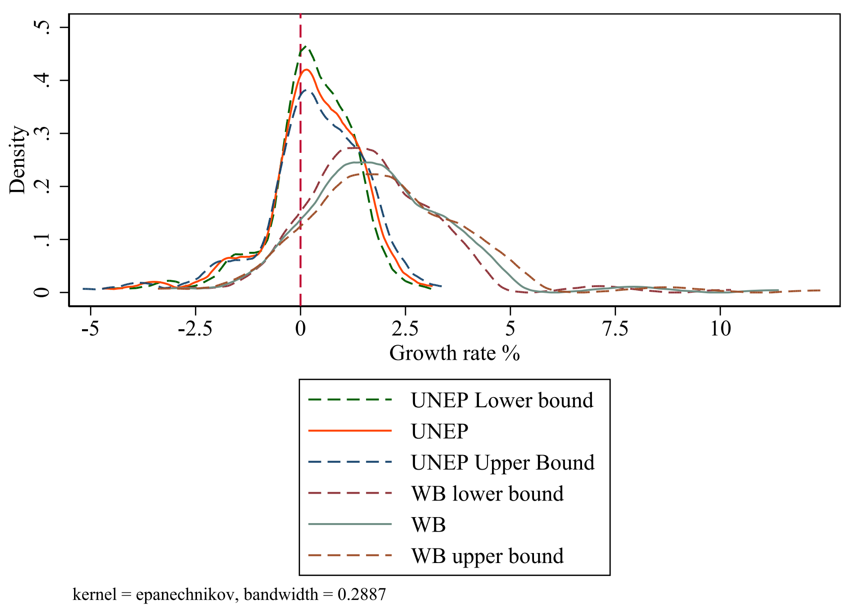

Fig. 14. Distribution of growth rates of UNEP wealth per capita, World Bank wealth per capita incorporating 10% error bands.

Moreover, wider efforts beyond the WB in gathering and estimating *GS* must be taken into account.

The UN SNA (2022) note that 'a significant analytical benefit from the consistent application of accounting approaches across different aspects of economic, environmental and social systems, is that it builds a set of data that can be meaningfully connected and integrated to support analysis across the different aspects'. As the UN SNA (2009) are being revised, UN SNA (2022) focuses on using national accounts to address issues relating to sustainability. While GDP has become 'one of the world's most well-known statistics', measuring wealth has some challenges to overcome before it can provide a more complementary set of statistics to GDP in national accounts. Utilising the SEEA is a first step towards a standardised wealth accounts, but the other issue which is more problematic is how best to account for changes in human capital and here there is still considerable refinement before it can be included in an agreed estimate of wealth. As noted in UN SNA (2022), assessing the role of human capital is gaining in importance, especially in relation to questions relating to productivity, but an assessment of how the approaches differ can be an important point for future work.[39]

Lastly, wealth accounting exercises take substantial time and resources to produce and there is a lag in terms of how these exercises can inform present policy. By this, we mean that the latest available estimate for wealth in World Bank (2021) was 2018 and in the recent update of UNEP (2023) the wealth estimates extend to 2019.

[39] At the time of writing, a draft chapter 35 on human capital was not yet available from the System of National 2025 webpage.

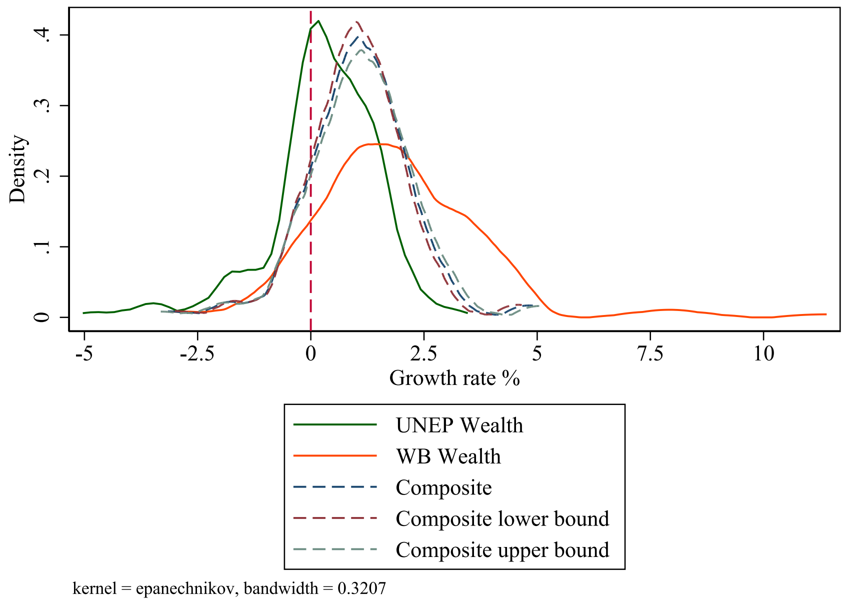

Fig. 15. Distribution of growth rates of UNEP wealth per capita, World Bank wealth per capita, and Compromise wealth.

Table 9
Correlation between indicators of change of wealth per capita (World Bank & United Nations) and GDP per capita growth.

	Δ w (WB) & GDP pc %	*Δw* (UNEP) & GDP pc %	GS & GDP pc %
Overall	0.684	0.256	0.162
	Geographic Region		
East Asia & Pacific	0.897	0.060	0.190
Europe	0.799	0.077	−0.361
Latin America	0.467	0.252	−0.023
Sub-Saharan Africa	0.521	0.385	0.400
Middle East & North Africa	0.853	0.247	0.206
North America	–	–	–
South Asia	0.903	0.718	0.770
	Income group		
Low	0.539	0.338	0.467
Lower Middle	0.630	0.099	0.403
Upper Middle	0.740	0.439	−0.059
High	0.836	0.441	−0.133

So while both of these reports were published post-Covid, neither are able to speak to the important question regarding the impact of the Covid-19 pandemic. In contrast to the wealth estimates, the latest GS estimates are for 2021.[40] Our proposal, therefore would be for semi-regular estimates of wealth to take stock of the position of wealth, but there should also be annual estimates of the *change* in wealth (with periodic assessments of the accuracy of these annual estimates and possibly incorporating further adjustment, as per Pezzey (2024)). This, in principle, would be similar to how decadal population censuses are combined with annual vital registration to make informed estimates of population change. Both exercises serve an important role and help inform policymaking, but an agreed methodology is necessary in order for this to be informative to policymakers.[41]

5. Conclusion

There have been calls to replace how we measure national economic activity, in a way which recognises the challenges of long-term sustainable development. The World Bank and the UNEP have been in the vanguard in efforts to change how we measure economic progress. Different working assumptions lead to very different outcomes and signals from these measures. We have illustrated the lack of coherence between the methodological approaches of both organisations, and the conflicting international signals on sustainability which result. These differences in estimated wealth do not help in the replacement, or complementarity, of GDP debates and may lead to sustainability trends, as measured by wealth changes, being ignored by policy makers, as confusing and contradictory signals. Future work needs to acknowledge these discrepancies and come to agreed standardisation in order for the concept to be used in any meaningful way. Reaching consensus on how changes in natural and human capital are measured seem to be key to resolving this problem. Finally, greater transparency is needed so that future researchers can assess the wealth estimates of both organisations. On this the World Bank leads the way as data is available on a bespoke website, similar open data policies from the UNEP would help with the uptake of a resilient wealth based approach to measuring sustainability. Without a transparent approach to data, we will be unable to get to the root of the divergence between both approaches and this will hinder further efforts in this space.

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CRediT authorship contribution statement

Eoin McLaughlin: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Cristián Ducoing:** Writing – review & editing, Writing – original draft, Validation, Formal analysis. **Nick Hanley:** Writing – review & editing, Writing – original draft, Formal analysis.

[40] Series NY.ADJ.SVNX.GN.ZS & NY.ADJ.SVNG.GN.ZS: World Development Indicators[Accessed 22 March 2024].

[41] McLaughlin et al. (2014) argue that GS was a more reliable indicator of sustainability over the long-run in the case of Britain than a metric based on the change in wealth.

Table 10
Countries with inconsistent metrics across World Bank, UNEP, and Compromise estimates.

Country	Region	Income	Resource Rents >20%	Population >2%
<0 wealth per capita growth (UNEP, WB, & Compromise)				
United Arab Emirates	Middle-East & North Africa	High	Y	Y
Bahrain	Middle-East & North Africa	High	Y	Y
Belize	Latin America & Caribbean	Upper-Middle	N	Y
Democratic Republic of Congo	Sub-Saharan Africa	Low	Y	Y
Iceland	Europe & Central Asia	High	N	N
Moldova	Europe & Central Asia	Upper-Middle	N	N
Niger	Sub-Saharan Africa	Low	N	Y
Papua New Guinea	East Asia & Pacific	Lower-middle	Y	Y
<0 WB; >0 UNEP & Compromise				
Jamaica	Latin America & Caribbean	Upper-Middle	N	N
Portugal	Europe	High	N	N
<0 UNEP & Compromise; >0 WB				
Gabon	Sub-Saharan Africa	Upper-Middle	Y	Y
Kuwait	Middle-East & North Africa	High	Y	Y
Pakistan	South Asia	Lower-Middle	N	Y
Qatar	Middle-East & North Africa	High	Y	Y
Saudi Arabia	Middle-East & North Africa	High	Y	Y
Venezuela	Latin America & Caribbean	Upper-middle	Y	N
<0 UNEP; >0 WB & Compromise				
Bolivia	Latin America & Caribbean	Lower-Middle	N	N
Brazil	Latin America & Caribbean	Upper-Middle	N	N
Central African Republic	Sub-Saharan Africa	Low	N	N
Canada	North America	High	N	N
Côte d'Ivoire	Sub-Saharan Africa	Lower-middle	N	Y
Cameroon	Sub-Saharan Africa	Lower-Middle	N	Y
Congo	Sub-Saharan Africa	Lower-Middle	Y	Y
Colombia	Latin America & Caribbean	Upper-middle	N	N
Ecuador	Latin America & Caribbean	Upper-Middle	N	N
Ghana	Sub-Saharan Africa	Lower-Middle	N	Y
Guatemala	Latin America & Caribbean	Upper-Middle	N	Y
Honduras	Latin America & Caribbean	Lower-Middle	N	Y
Iran	Middle-East & North Africa	Lower-Middle	Y	N
Iraq	Middle-East & North Africa	Upper-Middle	Y	Y
Kazakhstan	Europe & Central Asia	Upper-middle	N	N
Cambodia	East Asia & Pacific	Lower-middle	N	N
Lao PDR	East Asia & Pacific	Lower-middle	N	N
Lesotho	Sub-Saharan Africa	Lower-middle	N	N
Mongolia	East Asia & Pacific	Lower-middle	N	N
Mozambique	Sub-Saharan Africa	Low	N	Y
Mauritania	Sub-Saharan Africa	Lower-middle	N	Y
Peru	Latin America & Caribbean	Upper-middle	N	N
Paraguay	Latin America & Caribbean	Upper-middle	N	N
Senegal	Sub-Saharan Africa	Lower-middle	N	Y
Sierra Leone	Sub-Saharan Africa	Low	N	Y
Trinidad and Tobago	Latin America & Caribbean	High	N	N
South Africa	Sub-Saharan Africa	Upper-middle	N	N

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The underlying data is publicly available. The data used in the article will be made available on request.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.ecolecon.2024.108308.

References

Agarwal, P., Sawhney, A., 2021. Sustainability and comprehensive wealth accounting: The case of India. Environ. Dev. Sustain. 23, 3762–3786.

Arrow, K., Dasgupta, P., Goulder, L., Daily, G., Ehrlich, P., Heal, G., Levin, S., Maler, K.-G., Schneider, S., Starrett, D., Walker, B., 2004. Are we consuming too much? J. Econ. Perspect. 18 (3), 147–172.

Arrow, K.J., Dasgupta, P., Goulder, L.H., Mumford, K.J., Oleson, K., 2012. Sustainability and the measurement of wealth. Environ. Dev. Econ. 17 (03), 317–353.

Arrow, K., Dasgupta, P., Maler, K.-G., 2003. Evaluating projects and assessing sustainable development in imperfect economies. Environ. Res. Econ. 26, 647–685.

Asheim, G.B., Buchholz, W., Withagen, C., 2003. The Hartwick rule: Myths and facts. Environ. Res. Econ. 25 (2), 129–150.

Atkinson, G., Hamilton, K., 2003. Savings, growth and the resource curse hypothesis. World Dev. 31 (11), 1793–1807.

Bastien-Olvera, B., Moore, F., 2021. Use and non-use value of nature and the social cost of carbon. Nat. Sustain. 4, 101–108.

Blum, M., Ducoing, C., McLaughlin, E., 2017. A sustainable century? Genuine savings in developing and developed countries, 1900 - 2000. In: Hamilton, K., Hepburn, C. (Eds.), National Wealth What Is Missing, Why It Matters. Oxford Univ Pr.

Bolt, K., Matete, M., Clemens, M., 2002. Manual for calculating adjusted net savings. Environ. Dep. World Bank 1–23.

Clark, W.C., Harley, A.G., 2020. Sustainability science: Toward a synthesis. Ann. Rev. Environ. Res. 45 (331–86).

Damania, R., Polasky, S., Ruckelshaus, M., Russ, J., Chaplin-Kramer, R., Gerber, J., Hawthorne, P., Heger, M.P., Mamun, S., Ruta, G., Schmitt, R., Smith, J., Vogl, A., Wagner, F., 2023. Nature's Frontiers: Achieving Sustainability, Efficiency, and Prosperity with Natural Capital. World Bank, Washington D.C..

Dasgupta, P., 2001. Human Well-Being and the Natural Environment. Oxford University Press, Oxford.
Dasgupta, P., 2014. Measuring the wealth of nations. Ann. Rev. Res. Econ. 6, 17–31.
Dasgupta, P., Heal, G., 1974. The optimal depletion of exhaustible resources. Rev. Econ. Stud. 41 (128), 3–28.
Dasgupta, P., Managi, S., Kumar, P., 2022. The inclusive wealth index and sustainable development goals. Sustain. Sci. 17, 899–903.
Dearing, J.A., Wang, R., Zhang, K., Dyke, J.G., Haberl, H., Hossain, M.S., Langdon, P.G., Lenton, T.M., Raworth, K., Brown, S., Carstensen, J., Cole, M.J., Cornell, S.E., Dawson, T.P., Doncaster, C.P., Eigenbrod, F., Flörke, M., Jeffers, E., Mackay, A.W., Nykvist, B., Poppy, G.M., 2014. Safe and just operating spaces for regional social-ecological systems. Global Environ. Change 28, 227–238.
Duraiappah, A.K., Muñoz, P., 2012. Inclusive wealth: A tool for the united nations. Environ. Dev. Econ. 17 (3), 362–367.
Fenichel, E., Abbott, J.K., 2014. Natural capital: From metaphor to measurement. J. Assoc. Environ. Res. Econ. 1.
Ferreira, S., Vincent, J.R., 2005. Genuine savings : Leading indicator of sustainable development ? Econom. Dev. Cult. Chang. 53 (3), 737–754.
Fleurbaey, M., Blanchet, D., 2013. Beyond GDP: Measuring Welfare and Assessing Sustainability. Oxford University Press.
Greasley, D., Hanley, N., Kunnas, J., McLaughlin, E., Oxley, L., Warde, P., 2014. Testing genuine savings as a forward-looking indicator of future well-being over the (very) long-run. J. Environ. Econ. Manag. 67 (2), 171–188.
Hamilton, K., 1994. Green adjustments to GDP. Resour. Policy 20 (3), 155–168.
Hamilton, K., 2012. Comments on arrow others, 'sustainability and the measurement of wealth'. Environ. Dev. Econ. 17 (3), 356–361.
Hamilton, K., 2016. Measuring sustainability in the UN system of environmental-economic accounting. Environ. Res. Econ. 64 (1), 25–36.
Hamilton, K., Clemens, M., 1999. Genuine savings rates in developing countries. World Bank Econ. Rev. 13 (2), 333–356.
Hanley, N., Dupuy, L., Mclaughlin, E., 2015a. Genuine savings and sustainability. J. Econ. Surv. 29 (4), 779–806.
Hanley, N., Oxley, L., Greasley, D., McLaughlin, E., Blum, M., 2015b. Empirical testing of genuine savings as an indicator of weak sustainability: A three-country analysis of long-run trends. Environ. Res. Econ..
IPCC, 2021. Climate Change 2021: They Physical Science Basis. Technical Report, Intergovernmental Panel on Climate Change.
IPCC, 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability. Technical Report, IPCC.
Lindmark, M., Acar, S., 2013. Sustainability in the making? A historical estimate of Swedish sustainable and unsustainable development 1850–2000. Ecol. Econ. 86, 176–187.
Lindmark, M., Andersson, L.F., 2016. An historical wealth assessment – measuring the Swedish national wealth for the nineteenth and twentieth centuries. Scandinavian Econ. Hist. Rev. 64, 122–137.
Managi, S., Chen, S., Kumar, P., Dasgupta, P., 2024. Sustainable matrix beyond GDP: Investment for inclusive growth. Human. Soc. Sci. Commun. 11 (195).
McGrath, L., Hynes, S., McHale, J., 2021. The air we breathe: Estimates of air pollution extended genuine savings for Europe. Rev. Income Wealth.
McLaughlin, E., Ducoing, C., Oxley, L., 2023. Tracing genuine savings in the long run: Genuine savings estimates 1850 - 2018. NBER Working Papers 31155.
McLaughlin, E., Hanley, N., Greasley, D., Kunnas, J., Oxley, L., Warde, P., 2014. Historical wealth accounts for Britain: Progress and puzzles in measuring the sustainability of economic growth. Oxford Rev. Econ. Policy.
Meadows, D.H., Meadows, D.L., Randers, J., Behrens III, W.W., 1972. Limits to Growth.
Mota, R.P., Cunha-e-Sá, M.A., 2019. The role of technological progress in testing adjusted net savings: Evidence from OECD countries. Ecol. Econ. 164 (106382).
Muller, N.Z., 2014. Boosting GDP growth by accounting for the environment. Science.
Muller, N.Z., Mendelsohn, R., Nordhaus, W., 2011. Environmental accounting for pollution in the United States economy. Amer. Econ. Rev. 101.
Nature, 2023. GDP at 70: Why genuinely sustainable development means settling a debate at the heart of economics. Nature 620.
New Zealand Treasury, 2022. New Zealand's Wellbeing: Is It Sustainable and What are the Risks?. Technical Report, New Zealand Government.
Nordhaus, W.D., Tobin, J., 1973. The Measurement of Economic and Social Performance. NBER.
Pezzey, J.C.V., 2024. Adjusted net savings needs further adjusting: Reassessing human and resource factors in sustainability measurement. J. Environ. Econ. Manag. (102984).
Pezzey, J.C., Burke, P.J., 2014. Towards a more inclusive and precautionary indicator of global sustainability. Ecol. Econ. 106, 141–154.
Pezzey, J.C., Hanley, N., Turner, K., Tinch, D., 2006. Comparing augmented sustainability measures for Scotland: Is there a mismatch? Ecol. Econ. 57 (1), 60–74.
Polasky, S., Bryant, B., Hawthorne, P., Johnson, J., Keeler, B., Pennington, D., 2015. Inclusive wealth as a metric of sustainable development. Ann. Rev. Environ. Res. 40, 445–466.
Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S.E., Donges, J.F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., Petri, S., Porkka, M., Rahmstorf, S., Schaphoff, S., Thonicke, K., Tobian, A., Virkki, V., Wang-Erlandsson, L., Weber, L., Rockström, J., 2023. Earth beyond six of nine planetary boundaries. Sci. Adv. 9 (37), eadh2458.
Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., et al., 2009. A safe operating space for humanity. Nature 461.
Roman, P., Thiry, G., 2016. The inclusive wealth index. a critical appraisal. Ecol. Econ. 124, 185–192.
Rubio, M.d.M., 2004. The capital gains from trade are not enough: Evidence from the environmental accounts of Venezuela and Mexico. J. Environ. Econ. Manag. 48 (3), 1175–1191.
Sefton, J.A., Weale, M.R., 2006. The concept of income in a general equilibrium. Rev. Econ. Stud. 73 (1), 219–249.
Smulders, S., 2012. An arrow in the Achilles' heel of sustainability and wealth accounting. Environ. Dev. Econ. 17 (3), 368–372.
Solow, R.M., 1974. Intergenerational equity and exhaustible resources. Rev. Econ. Stud. 41, 29–45.
Solow, R., 1993. An almost practical step toward sustainability. Res. Policy 19 (3), 162–172.
Solow, R., 2012. A few comments on 'sustainability and the measurement of wealth'. Environ. Dev. Econ. 17, 354–355.
Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., Sörlin, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 347 (6223), 1259855.
Stiglitz, J.E., Sen, A., Fitoussi, J.-P., 2009. Report by the commission on the measurement of economic performance and social progress. Sustain. Dev. 12, 292.
UN, 2014. System of Environmental-Economic Accounting 2012—Central Framework. UN, EU, FAO, IMF, OECD, and World Bank.
UN SNA, 2009. System of National Accounts 2008. European Commission and IMF and OECD and UN and World Bank.
UN SNA, 2022. Chapter 2: National Accounts and Measures of Wellbeing and Sustainability Draft – Version 7. Technical Report, UN System of National Accounts.
UNEP, 2018a. Inclusive Wealth Report 2018 Appendix: Estimates of Inclusive Wealth of Nations by the Conventional Approach. United Nations, New York.
UNEP, 2018b. Inclusive Wealth Report 2018: Measuring Sustainability and Well Being. United Nations, New York.
UNEP, 2018c. Inclusive Wealth Report 2018 Methodological Annex: Conventional Approach. United Nations, New York.
UNEP, 2022. Inclusive Wealth Report 2022: Executive Summary. United Nations Environment Programme.
UNEP, 2023. Inclusive Wealth Report 2023: Measuring Sustainability and Equity. United Nations Environment Programme.
UNU-IHDP and UNEP, 2012. Inclusive Wealth Report 2012: Measuring Progress Toward Sustainability. Cambridge University Press.
UNU-IHDP and UNEP, 2014. Inclusive Wealth Report 2014: Measuring Progress Toward Sustainability. Cambridge University Press.
van Krevel, C., Peters, M., 2024. How natural resource rents, exports, and government resource revenues determine genuine savings: Causal evidence from oil, gas, and coal. World Dev. 181, 106657.
van Zyl, S., Au, J., 2018. The Start of a Conversation on the Value of New Zealand's Natural Capital. Technical Report, New Zealand Treasury.
Weitzman, M.L., 1997. Sustainability and technical progress. Scand. J. Econ. 99 (1), 1–13.
Weitzman, M., 1999. Pricing the limits to growth. Q. J. Econ. 114 (2), 691–706.
Weitzman, M., 2003. Income, Wealth, and the Maximum Principle. Harvard University Press.
World Bank, 1995. Monitoring environmental progress: A report on work in progress. The World Bank.
World Bank, 1997. Expanding the measure of wealth: Indicators of environmentally sustainable development. p. 112.
World Bank, 2006. Where is the Wealth of Nations?: Measuring Capital for the 21st Century. The World Bank.
World Bank, 2011. The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium. World Bank Publications.
World Bank, 2018. The Changing Wealth of Nations 2018: Building a Sustainable Future. The World Bank.
World Bank, 2021. The Changing Wealth of Nations 2021: Managing Assets for the Future. International Bank for Reconstruction and Development / The World Bank, Washington, DC.
World Bank, 2022a. World bank country and lending groups. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. (Accessed: 16 Sep 2022).
World Bank, 2022b. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators. (Accessed: 16 Sep 2022).

Yamaguchi, R., Islam, M., Managi, S., 2022. Natural capital and wealth accounting for sustainability assessment: A global perspective. Int. Rev. Environ. Res. Econ. 16, 431–465.
Yamaguchi, R., Islam, M., Managi, S., 2019. Inclusive wealth in the twenty-first century: A summary and further discussion of inclusive wealth report 2018. Lett. Spatial Res. Sci. 12, 101–111.
Yun, S.D., Hutniczak, B., Abbott, J.K., Fenichel, E.P., 2017. Ecosystem-based management and the wealth of ecosystems. Proc. Natl. Acad. Sci. USA 114 (25), 6539–6544.

Further reading

Asheim, G.B., 1986. Hartwick's rule in open economies. Can. J. Econ. 395–402.
Asheim, G.B., Hartwick, J.M., Yamaguchi, R., 2023. Sustainable per capita consumption under population growth. Resour. Energy Econ..
Atkinson, G., Hamilton, K., 2007. Progress along the path: evolving issues in the measurement of genuine saving. Environ. Res. Econ. 37, 43–61.
Banzhaf, H.S., 2005. Green price indices. J. Environ. Econ. Manag. 49, 262–280.
Banzhaf, H.S., 2020. A history of pricing pollution (or, why Pigouvian taxes are not necessarily Pigouvian). NBER Working Papers No. 27683.
Ferreira, S., Hamilton, K., Vincent, J.R., 2008. Comprehensive wealth and future consumption: Accounting for population growth. World Bank Econ. Rev. 22 (2), 233–248.
Hamilton, K., Hartwick, J.M., 2005. Investing exhaustible resource rents and the path of consumption. Can. J. Econ. 38 (2), 615–621.
Hamilton, K., Liu, G., 2014. Human capital, tangible wealth, and the intangible capital residual. Oxford Rev. Econ. Policy 30 (1), 70–91.
Hamilton, K., Ruta, G., Tajibaeva, L., 2006. Capital accumulation and resource depletion: A Hartwick rule counterfactual. Environ. Res. Econ. 34 (4), 517–533.
Hartwick, J., 1977. Intergenerational equity and the investing of rents from exhaustible resources. Am. Econ. Rev..
Inklaar, R., G.U., W., Diewert, E., 2023. Deflation in the Changing Wealth of Nations database. Technical Report.
Jorgenson, D.W., Fraumeni, B.M., 1992. The output of the education sector. In: Output Measurement in the Service Sectors. University of Chicago Press, pp. 303–341.
Mäler, K.-G., 1991. National accounts and environmental resources. Environ. Res. Econ. 1, 1–15.
McGrath, L., Hynes, S., McHale, J., 2019. Augmenting the World Bank's estimates: Ireland's genuine savings through boom and bust. Ecol. Econ. 165 (106364).
Pezzey, J.C.V., 2004. One-sided sustainability tests with amenities and changes in technology, trade and population. J. Environ. Econ. Manag. 48, 613–631.
Pillarisetti, J., 2005. The World Bank's 'genuine savings' measure and sustainability. Ecol. Econ. 55, 599–609.
Qasim, M., Oxley, L., McLaughlin, E., 2020. Genuine savings as a test of New Zealand weak sustainability. Environ. Dev. Sustain. 22 (1), 89–127.
Solow, R.M., 1956. A contribution to the theory of economic growth. Q. J. Econ. 70 (1), 65–94.
UN, 2023. National accounts - analysis of main aggregates (AMA). https://unstats.un.org/unsd/snaama/Downloads. (Accessed: 24 April 2023).
van der Ploeg, F., 2011. Natural resources: Curse or blessing? J. Econ. Lit. 49 (2), 366–420.
Vincent, J.R., 1997. Testing for environmental kuznets curves within a developing country. Environ. Dev. Econ. 2 (4), 417–431.