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CHALLENGES OF WEALTH-BASED SUSTAINABILITY METRICS:

A CRITICAL APPRAISAL

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JEL: Q01, Q32, Q56, N10, O13, O44

Challenges of wealth-based sustainability metrics: A critical appraisal*

Eoin McLaughlin[†], Cristián Ducoing[‡], and Nick Hanley[§]

March 2024

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- 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. At the most extreme, countries that perform the worst according to the UN are shown to perform well according to the World Bank. This confusion in signals makes better policy making more difficult.

Keywords: Wealth, Sustainability, Natural Capital, Sustainable Development

JEL Codes: Q01, Q32, Q56, N50, N10, O13, O44

*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. We would also like to thank Matthew Agarwala and Robert Marks for comments and suggestions on a previous draft.

[†]Department of Accounting, Economics, and Finance, Heriot-Watt University, UK. e.mclaughlin@hw.ac.uk

[‡]Department of Economic History, Lund University, Sweden & Department of Economics, Public University of Navarre, Spain. cristian.ducoing@ekh.lu.se

[§]School of Biodiversity, One Health, & Veterinary Science, University of Glasgow, UK Nicholas.Hanley@glasgow.ac.uk

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; Stiglitz et al., 2009; Fleurbaey and Blanchet, 2013)).[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'. 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., 2015) - see Appendix 1 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, and human) 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, 2018a). 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 misaligned sustainability 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 Figure 1).[5] 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 (2018a)'s approach estimates that 45 out of 140 countries experienced negative change in wealth per person.[6] Table 1 shows a comparison of both World Bank and UNEP estimates across a comparable time period (1995-2014); in that period 17

[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 initatives 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); 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).

[5] 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.

[6] The World Bank period of reference is 1995-2018, while the UN period of reference is 1990-2014.

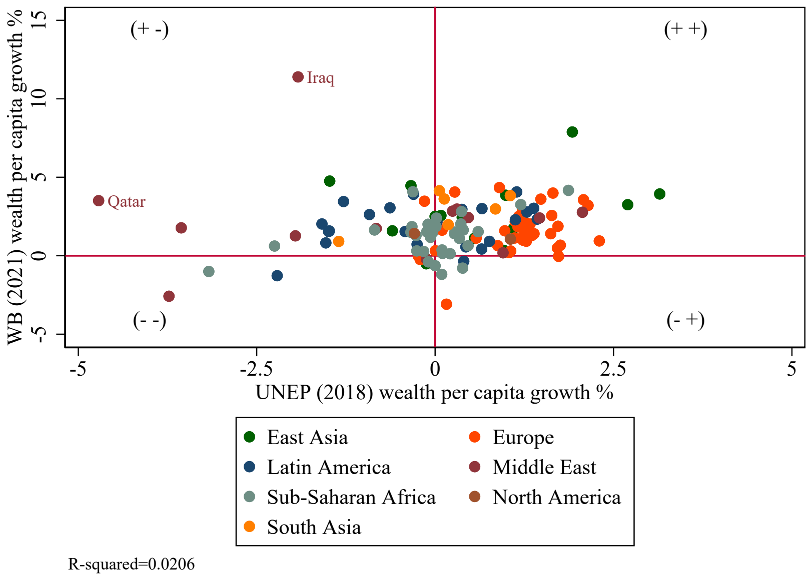

Figure 1: Growth in Wealth per capita
Sources: World Bank (2021); UNEP (2018a,b).
Note: World Bank (2021) reports wealth data for 146 countries from 1995-2018. UNEP (2018a) reports wealth data for 140 countries from 1990-2014. Only 128 countries are reported in both WB and UNEP data, only these data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

countries on the World Bank list are reported as negative while the UN reports 44 as negative. Moreover, there is little cross-over in terms of which specific countries that show unsustainable paths (see Figure 1); only 9 of the 45 countries experiencing negative growth in the (UNEP, 2018a) 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.[7]

The World Bank has deemed that *CWON* reports will be 'regular publication that will be updated repeatedly' (World Bank, 2021, p.49). While the latest UNEP (UNEP) report notes '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.' This note shows that while these bodies may agree in principle, the empirical application differs significantly, producing confusing signals for policy makers.

While it is known that there are two major international organisations providing estimates of wealth, we find limited evidence of dialogue between both the respective research groups behind the wealth accounts at both the World Bank and United Nations.[9] For example, Damania et al. (2023), in one of

[7]There are also several countries clustered around 0 in Figure 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 %.[8]. Given the clustering around 0, this could indicate that the estimates of wealth are not sufficiently precise for us to make any comparison.

[9]There has been relatively little academic engagement with the latest CWON project, with only 42 cites as of February 2024 for

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 (2018a) is omitted in this discussion. As we document in Figure 1 there is no clear cut signal emerging from the work of either institution. Similarly, Yamaguchi et al. (2022), some of the authors of the UNEP (2018a), do not comment on or explain differences between the *CWON* and the UNEP (2018a) report.

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.[10] The major message from our study is the need for an agreement to standardise wealth accounting, in a similar vein to what is done for national income (i.e., (UN, 2009)) and for reporting bodies to adhere to a standardised accounting framework.[11]

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 measures of wealth (Hamilton, 2016). However, as shown above, estimating human capital is equally problematic and an agreed framework is necessary in order to fully incorporate this important aspect of capital into estimates of wealth.

2 Measuring wealth and the change in wealth in practice

While there are strong theoretical foundations underpinning the wealth concepts, 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 the idealised view of capital is more complicated.

The World Bank has been at the vanguard in the push for a shift in focus from income to 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*" [12]

The UNEP is another pioneer the development of wealth accounts. The UNEP has published these estimates since 2012 (UNU-IHDP and UNEP, 2012, 2014; UNEP, 2018a), with a recently updated version

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 inlcude Dasgupta et al. (2022). In terms of policy papers, van Zyl and Au (2018); New Zealand Treasury (New Zealand Treasury) both cite the IWR reports.

[10] 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.

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

[12] 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.

scheduled for release. The coverage of UNEP (2018a,b) provide estimates of wealth from 1990 to 2014. UNEP draw on the wealth framework of Dasgupta (2001) and reproduce equations derived by Arrow et al. (2004) and Dasgupta (2001) (equations 3 and 5 in Appendix 5) (UNEP, 2018a, p.3).[13] 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.

The conceptual distinction between W and GS is that W measures the aggregate stock of wealth and GS (equation 7) measures changes in wealth, but not wealth directly. 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. In terms of 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.

For K_N, the distinction primarily relates not so much to what elements of K_N are measured (see Figures 2 and 3) but *how* they are valued. 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 cost) (UNEP, 2018c, p.11).

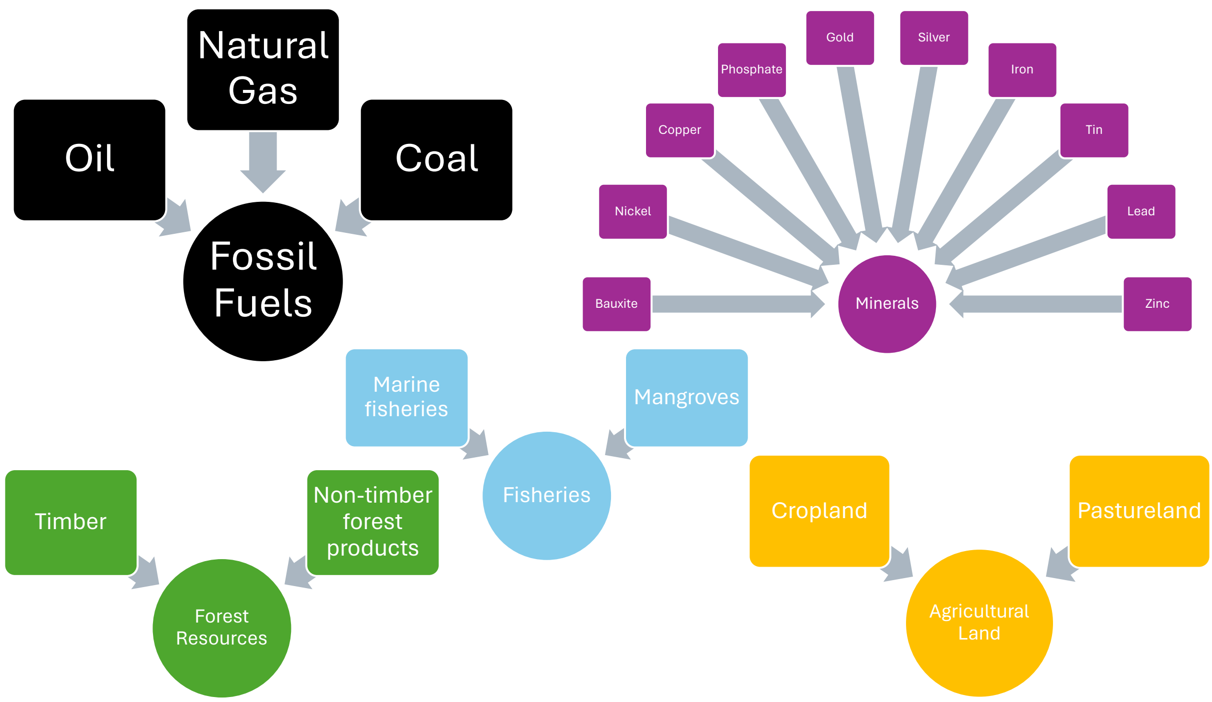

Figure 2: CWON Components of Natural capital

The primary difference between the World Bank and UNEP measures of K_N, in terms of what is included, relate to forest resources. Both UNEP & World Bank include timber, WB counts 'non-timber

[13] Duraiappah and Muñoz (2012), two UN based economists, discuss the benefits of the Arrow et al. (2012) methodology although they highlight challenges in making the framework operational.

Table 1: Distinction between Wealth (Comprehensive & Inclusive) and change in wealth (Genuine Savings)

	Comprehensive (World bank)	Inclusive (UNEP)	GS
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, urban land)	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)	Particulate damage & CO2 emissions
Adjustments		Total Factor Productivity Carbon damage Oil Capital Gains	

Sources: World Bank (2021); UNEP (2018a); Yamaguchi et al. (2019); Hamilton and Clemens (1999); Bolt et al. (2002)

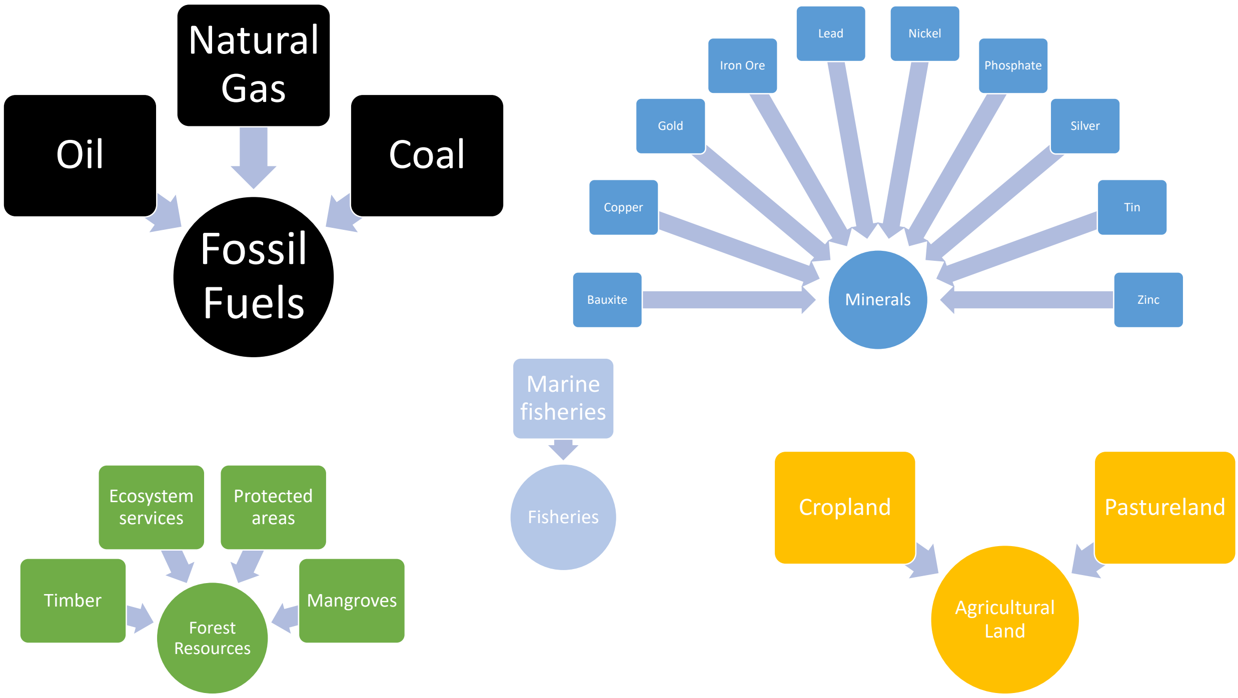

Figure 3: UNEP Components of Natural capital

forest products' but this is not further elaborated upon. UNEP includes ecosystem services, protected areas, and mangroves. 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 (2009).[14]

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 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). [15]

Pollution, is treated differently in both. In *W* it is only included indirectly in terms of the impact it has on the depreciation of the various forms of capital. UNEP (2018a) include carbon damages as an adjustment to the benchmark *W* estimate, however the indirect impact that climate change has on the various forms of capital run the risk that UNEP (2018a) is double counting carbon damages. In *GS*

[14] 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.'

[15] 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).

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* include an adjustment to the benchmark estimates to includes a measure of technological change (i.e. Z from Equation 2).[16] The theoretical literature deems technological progress to be an integral aspect of sustainability (Weitzman, 1997, 1999). Also, 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). Therefore, incorporation 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 UN, as well as *GS* is shown in Tables 2 and 3.[17] The coverage of Δw from the UN 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).[18] 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).[19]

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

Figure 4 and Table 3 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

[16] 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 of 'merely to add TFP growth to comprehensive investment' is ('we need only to add TFP growth rate to the inclusive growth rate').

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

[18] 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 UN (2014) and World Bank (2011) methodologies.

[19] 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., 2015; Blum et al., 2017; McLaughlin et al., 2023).

Table 2: Comparison of data coverage

	Δ w		
	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
	Δ W <0 (Reference period: 1995-2014)		
Total number of countries	7	4	37
	Δ w <0 (Reference period: 1995-2014)		
Total number of countries	44	17	-

Note: The comparisons are of benchmark estimates of W & w UNEP (2018b); World Bank (2021) and do not include the adjustments outlined in Table 1. Sources: UNEP (2018b); World Bank (2021, 2022b). Income groups and region classification derived from World Bank (2022a)

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 Low and 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.

At a glance, the correlation coefficients appear to suggest that the natural resource dependence may be a driver of the conflicting findings. Table 4 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.[20] The dependent variables here are the growth in Δ w as measured by CWON and IWR and Δ W 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 (2018b).[21] The tables 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

[20]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.

[21]Table 6 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, paritcularly for GDP growth, coal rents, and gas rents.

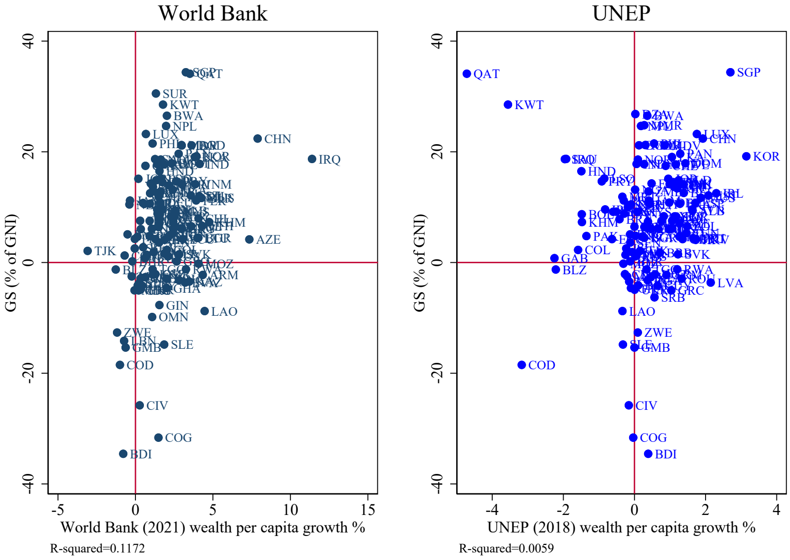

Figure 4: Change in wealth and Genuine Savings

	Δw (WB) & Δ w (UN)	Δw(UN) & GS	Δ w (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

Table 3: Correlation between indicators of change of wealth (World Bank & United Nations)

negative for GS. The coefficients for regional dummies also differ in size and signficance 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.

While the evidence from Table 4 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 variation. Oil rents in particular have differing impacts on the growth of wealth per capita in the World Bank and UN measures of wealth per capita, but the impacts appear to be low. This is further explored in Figure 5 which looks at the growth in the various types of capitals that make up wealth (e.g., as shown in Table 1). Figure 5 purposely uses the same scales across each quadrant and includes R-squared

	(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)		

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4: Regression of changes in wealth, 1995-2014

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.

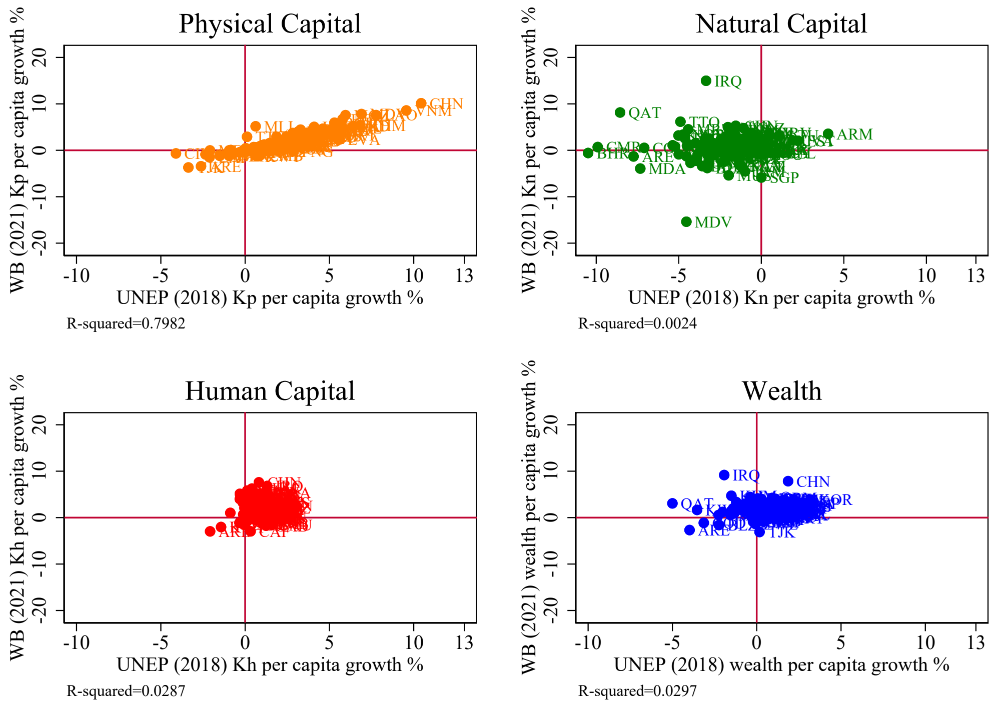

Figure 5: Comparing the Components

of the capital estimates.[22] Unsurprisingly, the closest match is physical capital as both World Bank (2021) and UNEP (2018a) 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.[23] As shown in Table 1, this differences reflects different methodological approaches to valuing human capital, one based on discounted life times earnings and another on returns to education. As natural capital and human capital are large components of wealth in low-income and high income countries respectively, this explains the difference in the underlying estimates of the change of wealth. 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.[24] Figure 6 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

[22]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.

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

[24]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)

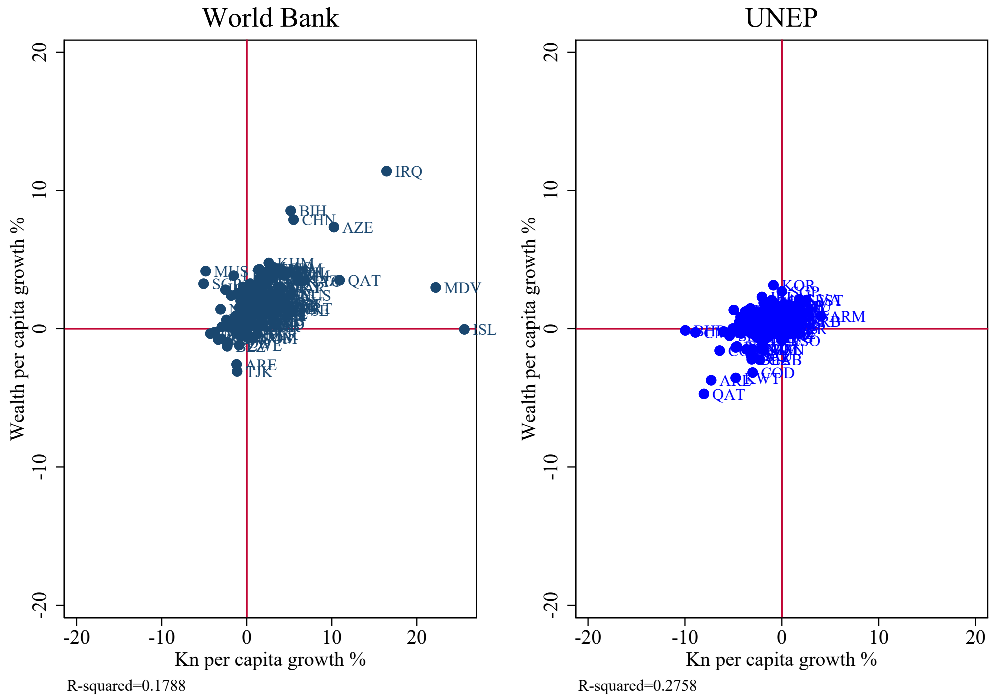

Figure 6: Comparing Growth in Wealth per capita and Natural Capital per capita

countries in the UNEP data show negative natural capital per capita growth which is the opposite of the signal from World Bank data, see Figure 7.

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?

As Figure 8 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 UN measure of the change in wealth (see Figure 19). [25]

This is further elaborated in pairwise correlations across regions and income categories, shown in Table 5. 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 strong correlated in South Asia and is highest in the Upper Middle Income and High Income countries. Table 5 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.

[25] 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.

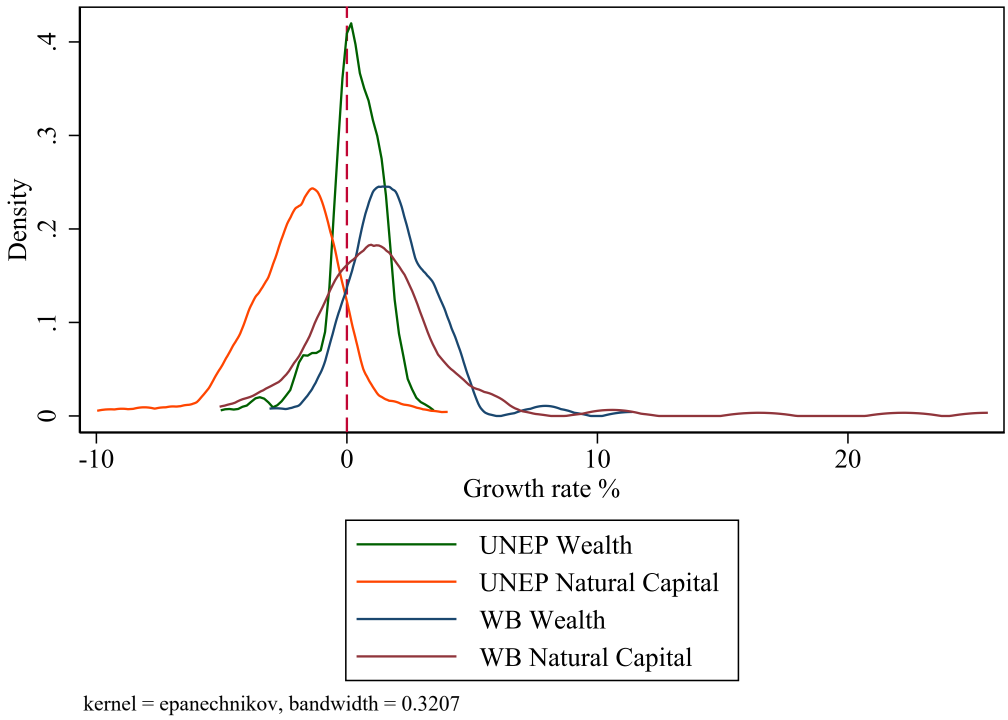

Figure 7: Distribution of Growth in Wealth per capita and Natural Capital per capita

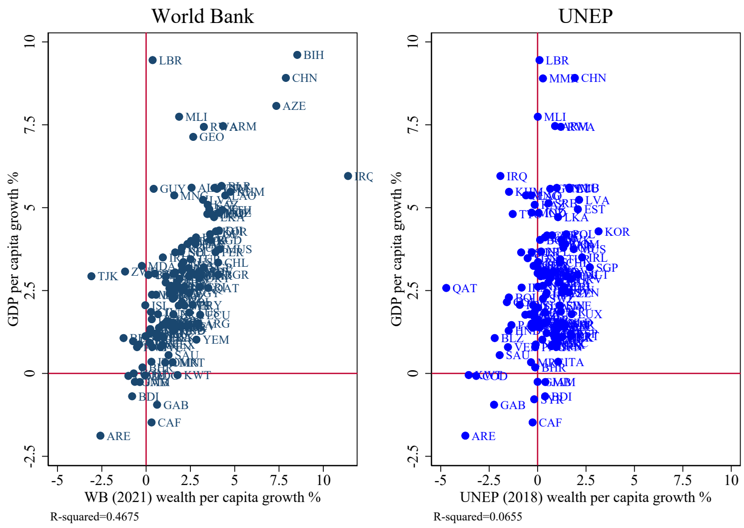

Figure 8: Wealth per capita growth and GDP per capita growth

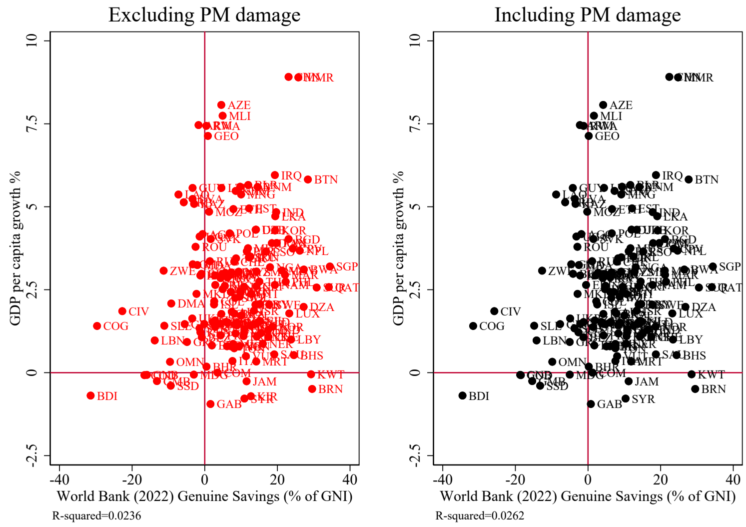

Figure 9: Genuine Savings and GDP per capita growth

	Δw (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

Table 5: Correlation between indicators of change of wealth (World Bank & United Nations) and GDP per capita growth

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.[26]

Perhaps the differences in output is merely a result of the use of different sources of information.

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

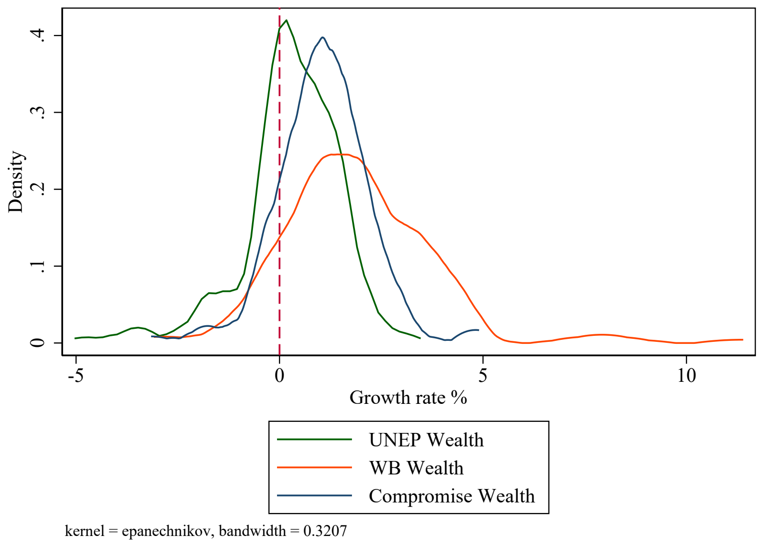

Figure 10: Distribution of growth rates of UN wealth per capita, World Bank wealth per capita, and Compromise wealth

However, as these are global estimates, inevitably similar data sources will be used to derive these estimates.[27] 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. It could also be argued that the figures from the both the UNEP and World Bank represent a continuum and somewhere in between represents the "true" range of sustainability. Figure 10 represents such a range by making a compromise figure which is an unweighted average of both approaches. The compromise figure has a mean of 1.06 %, which is equidistant from the mean of the UN (0.29 %) and the World Bank (1.82 %). There are 8 countries that are shown as negative growth in wealth per capita on each metric.[28] There are 6 countries that are negative for both the UNEP list and the compromise list but positive on the World Bank list.[29] 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.[30]

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, someone in between still requires some remedial action. The answer is simple 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 harmonize data across

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

[28]UAE, Bahrain, Belize, Democratic Republic of Congo, Iceland, Moldova, Niger, and Papua New Guinea.

[29]These countries are: Gabon, Kuwait, Pakistan, Qatar, Saudi Arabia, Venezuela.

[30]These countries are: Bolivia, Brazil, Central African Republic, Canada,Côte d'Ivoire, Cameroon, Congo, Colombia, Ecuador, Ghana, Guatemala, Honduras, Iran, Iraq, Kazakhstan, Cambodia,Lao PDR,Lesotho, Mongolia, Mozambique, Mauritania, Peru,Paraguay, Senegal, Sierra Leone, Trinidad and Tobago,South Africa.

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. 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 (2009) are been 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 to be included in agreed estimates 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 different approaches differ can be an important point for future work.[31]

Lastly, wealth accounting exercises take substantial time and resources 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 UN (2023) the wealth estimates extend to 2019. So while both of these reports were published post-Covid, neither are able to speak to the important question regarding the impact of Covid-19 pandemic. In contrast to the wealth estimates, the latest GS estimates are for 2021.[32] Our proposal therefore would be for semi-regular estimates of wealth to take stock of the position of wealth but for annual updates to the change in wealth with assessments of the accuracy of these annual updates over time. This in principle would be similar to decadal population censuses combined with annual vital registration to make informed estimates of population change. Both exercises serve a role a important and help inform policymaking, but an agreed methodology is necessary in order for this to be informative to policymakers.[33]

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. However, there is an urgent call to increase dialogue between stakeholders about how we account for changes in wealth. Different assumptions lead to very different outcomes and signals from these measures. We have illustrated the lack of coherence between the research programmes of both organisations, and the conflicting international signals on sustainability which result. These differences in estimated wealth do not help

[31] A draft chapter 35 on human capital is not yet available from the System of National 2025 webpage.

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

[33] 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.

in the replacement, or complementarity, of GDP debates. 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 reseachers 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.

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Appendices

A1 Measuring the Economy: past, present, and future

Modern measurement of the economy dates from the mid-twentieth century. Constructed to quantify the monetary value of all goods and services entering into market exchange, Gross Domestic Product (GDP) is regarded as the 'invention of the 20th century' (Landefeld, 2000; Coyle, 2017; Masood, 2016). Data to allow the construction of GDP estimates is now standardized world-wide, adding to the usefulness of this indicator (e.g., (UN, 2009). However, there is a growing recognition that maximizing year on year growth in GDP is unlikely to be an achievable and/or desirable target for the twenty-first century due to numerous negative consequences, and that *sustainable development* has become the key to global survival (Rockström et al., 2009, 2013; Steffen et al., 2015; Richardson et al., 2023).[34]

One way GDP is conventionally measured (from the expenditure side of the economy) is from the following accounting identity:

$$GDP = C + I + G + NX \tag{1}$$

Where GDP is the sum of consumption (*C*), investment (*I*), Government consumption (*G*), and net exports (*NX*).

When constructing GDP estimates, factors that have negative impacts on society (e.g., pollution) are given equal weight to elements that are beneficial for society. By this we mean production that involves

[34] Although, in academic economics the focus is not on GDP maximisation per se, but on the present value of utility (or social welfare) that are maximised (e.g. as in Ramsey (1928)).

pollution enter GDP without accounting for the social cost of pollution. Furthermore, pollution control efforts show up as a benefit to society when they are actually mitigating social costs, so called defensive expenditures (UN SNA, 2022, 2.37 & 2.38). The recent IPCC (2021) report includes dire warnings of the dangers of future climate change, which, in the main, has been a direct consequence of following a GDP maximization goal. Unsurprisingly, there is now a growing call for changes to be made to how we measure economic activity, economic development and wellbeing more generally (Stiglitz et al., 2009, 2018) and for for greater integration of economics and sustainable development (Polasky et al., 2019; White House, 2023). One avenue in which this is being expressed is through a shift in focus from measuring national income to measuring national wealth.

A well-defined economic theory of sustainability uses wealth as a starting point.[35] For example, see the treatment of the concept in Dasgupta (2001) & Weitzman (2003) where wealth is defined broadly and comprehensively. For Dasgupta (2001) this means defining wealth as 'as the social worth of an economy's entire capital base',[36] while for Weitzman (2003) this means a definition of wealth where 'the underlying ideal is to have the list of capital goods be as comprehensive as possible'.[37]

Dasgupta (2001) expresses an economy's wealth at a specific point in time as:

$$W_t = \sum_i (p_{it} K_{it}) + \sum_j (h_{jt} H_{jt}) + \sum_k (r_{kt} S_{kt}) + \sum_m (q_{mt} Z_{mt}) \tag{2}$$

That is wealth is composed of the value (price x quantity) of different forms of capital; manufactured (K), human (H), natural (S), and knowledge (Z) (Dasgupta, 2001, eq 9.1).[38] Wealth relates to sustainable development through its relationship with well-being. Specifically, Arrow et al. (2004) defines sustainability as a relationship between between well-being and wealth. Firstly, defining wealth as the present value of future well-being, as in equation 3:

$$V_t = \int_{s=t}^{\infty} U[C_{(s)}] e^{-\delta(s-t)} ds \tag{3}$$

and then by equating well-being and wealth, whereby:

$$V_t = V(K_t) \tag{4}$$

Alternatively, wealth is seen as the foundation of future income and hence well-being, as changes in wealth (due to saving/investment) provide an indication of the feasibility of future, sustainable, development paths (Weitzman, 2017); where sustainable development is defined as non-declining wellbeing over time for the representative agent (Hanley et al., 2015). In effect, this sees a country's income (e.g., GNP) as effectively a return on its assets (wealth or capital) (Weitzman, 1976). These assets are comprised of produced, human, and natural capital. Defining income becomes slightly more problematic, for example Weitzman (2017) highlights the differing definitions of Fisher (1930) (the net return on capital wealth over a period), Lindahl (1933) (the sum of consumption plus the increase in wealth over a period), and Hicks (1946) ('the maximum amount which can be spent during a period if

35 This draws on an older literature on the link between wealth and income (Hicks, 1946; Samuelson, 1961).

36 Arrow et al. (2004), where Dasgupta is second author, define wealth as 'genuine wealth is the accounting value of all capital assets, including population.'

37 In later work Weitzman (2016) expanded on this definition of wealth as an 'all-encompassing' measure of capital and 'Generally speaking, every possible type of capital ought to be included - to the extent that we know how to measure and evaluate at efficiency prices the associated flow of net investments'.

38 While Weitzman (2003) shares this view he defines wealth in a more general way: $W_{(t)} \equiv V(K^*_{(t)})$. Where K is a composite index of all forms of capital: $K = K_i$

there is to be an expectation of maintaining intact the capital value of prospective receipts in money terms').[39] Weitzman (2017) connects these concepts of income with a measure of comprehensive wealth, whereby effectively income, however defined, is a return on wealth. This is effectively the approach of the World Bank (World Bank, 2021, figure 1.1). Furthermore, the relationship between national income, GDP, and wealth comes from how economists perceive income to be derived from a production function, which is based on capital stock (physical), as in Solow (1956), and then extended to include natural capital, as in **?**, and other forms of capital.[40]

Change in wealth and social welfare

As shown in Arrow et al. (2004, 2012), the current change in wealth is equal to the discounted value of social welfare over time, providing a theoretical link between wealth accounting and sustainable development as a concept. Arrow et al. (2004) the change in the capital stock gives an indication of sustainability. Such that:

$$dV/dt = \sum_i (\partial V/\partial K_{it})(dK_{it}/dt) = \sum p_{it} I_{it} \tag{5}$$

where, $\sum p_{it} I_{it}$ refers to the 'genuine investment as the change in society's genuine wealth', with p_{it} the shadow price and I_{it} the change in the the capital stock.

Dasgupta (2001) defines how wealth increases, namely if there is net investment in the capital stock, defined as:

$$I_t = \sum_i (p_{it} dK_{it}/d_t) + \sum_j (h_{jt} dH_{jt}/d_t) + \sum_k (r_{kt} dS_{kt}/d_t) + \sum_m (q_{mt} dZ_{mt}/d_t) \tag{6}$$

Where I_t measures the 'change in wealth' at time *t* (Dasgupta, 2001, eq 9.2).[41] Here the change in quantity of the stocks of capital are multiplied by constant accounting, or shadow prices, where p_{it}, refers to the shadow price of produced capital, h_{jt} is the shadow price of human capital, r_{kt} is the shadow price of natural capital, and q_{mt} is the shadow price of technology. "

Here we see a connection between our accounting identity (equation 1) and the change in wealth in equations 5 and 6, this is through investment. However, equations 5 and 6 define investment more broadly.

.0.1 Genuine Savings

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*)[42]. 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

[39] Hicks (1946) outlined three concepts of income circulating a central definition of income that, 'a man's income as the maximum value which he can consume during a week, and still expect to be as well off at the end of the week as he was at the beginning. Thus, when a person saves, he plans to be better off in the future; when he lives beyond his income, he plans to be worse off'. The first definition is that cited above, the second refers to the context when the interest rate changes, and the third considers changes in prices (Hicks, 1946, chapter 14)

[40] $Y_t = f(W_t)$, Where Y represents income, e.g. income as in equation 1, and W represents wealth along the lines represented in equation 2. Although, also see Solow (2012b) for a critical perspective on the application of wealth concepts outlined here.

[41] Likewise, Weitzman (2003) defines the change in wealth as net investment ($I_{i(t)} = \dot{K}_{i(t)}$).

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

and Clemens, 1999). The World Bank continues to provide estimates of Adjusted Net Savings.[43]

GS is calculated by the following equation:

$$GS = GNI - C - \delta K - n(\Delta N) - \sigma Pol + m \tag{7}$$

Where Genuine Savings (*GS*) are derived from Gross National Income[44] (GNP) minus consumption (C) (i.e., savings), the depreciation rate of produced capital (δK), the value of resource rents (n(ΔN)), the value of pollution damages (σ Pol),[45] and change in human capital (proxied by education expenditure, *m*).

While it may not be immediately apparent, there is a clear relationship between equation 7 and equation 6. This stems from the theoretical view that equates savings with investment, such as the 'savings-investment identity' as used in Solow (1956). The other aspects of equation 7 are either direct or indirect variants of the elements in equations 6. Using equation 1, we can substitute GNP in equation 7, where GNI = GDP + Net receipts:

$$GS = [C + I + G + NX + nr] - C - \delta K - n(\Delta N) - \sigma Pol + m \tag{8}$$

$$= (I - \delta K) + G + NX + nr - n(\Delta N) - \sigma Pol + m \tag{9}$$

If we ignore G and nr, this becomes:

$$gs = \dot{K} + p_S \dot{S} + p_H \dot{H} + NX \tag{10}$$

The *CWON 2021* report emphasises the importance of the *change* in wealth per capita (Δw) as an indicator of sustainable development and that Δw provides 'a forward looking indicator of sustainability' (World Bank, 2021, p.28, p. 29). Equation 11 represents *changes* in wealth per capita (with lower case symbols representing division by population) that are derived from *W*. Note, there is no formal equation of wealth or the change in wealth presented in World Bank (2021).

$$\Delta w = \Delta k_P + \Delta k_N + \Delta k_H + \Delta net_{FA} \tag{11}$$

Whilst a set of theoretical papers focus on changes in wealth at constant prices, empirical estimates of changes in marketed elements of the natural capital stock typically reflect changes in both real output prices and (marginal) extraction costs in their computations of resource depletion costs.

The main drivers of Δk_P are depreciation (-) and investment (+). The drivers of Δ k_N for nonrenewables are extraction (-), reduction in economic reserves from either a fall in market prices or an increase in extraction costs (-), and increases in economic reserves (and new discoveries) because of higher prices or lower extraction costs (+). For renewables Δk_N is driven by the rate of net natural growth, minus harvesting (+ or -). For Δk_H this depends on prevailing wage rates, education levels, and labour force growth (population growth and net migration).

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

[44] The distinction between Gross National Income and Gross Domestic Product presented in Equation 1 is that GNP is GDP + net overseas income (UN, 2009, Chapter 2, 2.143)

[45] This is how the World Bank calcualtes GS, but this can also be seen as depreciation of natural capital and changes in health capital.

In per capita terms, GS becomes

$$gs = \dot{k} + k_g + p_s(\dot{s} + sg) + p_h(\dot{h} + h_g) + (FA + fa_g) \tag{12}$$

Where NX is defined as δFA and g is the population growth rate. From this equation, it is clear that GS includes capital dilution.

GS is seen as a complementary indicator to Δw and has 'the advantage of being easy to understand'. This is drawn from the earlier theoretical work of Hamilton and Clemens (1999) that showed how positive/negative *GS* implies sustainable/unsustainable paths.[46] However, *GS* is criticised for only providing a partial view of how wealth changes (World Bank, 2021, p.51).[47]. Much of this difference arises because GS is embedded within a UN (2009) framework for definitions of savings and investment, while wealth measures are not limited by SNA conventions. For example, there are differences in how the change in human capital is measured, how resource discoveries are treated, and capital gains. The *CWON 2021* states that the 'preferred measure of sustainability is the change in total wealth per capita' (World Bank, 2021, p.54). However, empirical evidence to support this preference is not provided, whereas there is now a large body of work providing evidence that GS is a good predictor of future well-being over the long-run (Ferreira and Vincent, 2005; Ferreira et al., 2008; Hamilton and Hartwick, 2005; Greasley et al., 2014).

Conceptually, this new metric (Δw) is not too dissimilar from GS per capita. Aspects that drive the change in wealth in equation 11 are represented in equation 7. However, notable differences are capital gains and the discovery of new resources, although it is possible to include capital gains (Rubio, 2004; Pezzey et al., 2006) and resource discoveries (Qasim et al., 2020) in GS estimates.

One of the main reasons for giving the change in wealth per capita preferential treatment is argued to be because it takes account of population growth. In World Bank publications *GS* is traditionally presented as a percentage of GNI or GDP for cross-country comparability, but GS can be presented in per capita terms (*GS*/Population) using information provided in the World Bank (2022b). In fact, this is the approach in the existing academic literature where the metric analysed is a per capita measure of *GS* (Ferreira and Vincent, 2005; Ferreira et al., 2008; Greasley et al., 2014; Asheim et al., 2023). However, this conversion does not address the issue of wealth dilution and this needs to be addressed to make GS per capita and the change in wealth per capita comparable (Asheim et al., 2023), as is done in Ferreira et al. (2008) and Greasley et al. (2014) for example.

Whilst the basic theoretical framework for the wealth accounting approach to measuring the sustainability of economic development has been established, there are several important disagreements on how different components of changes in wealth should be valued. These disagreements help explain why the practical methodologies developed by the WB and UNEP can send conflicting signals.

Critiques

In this section, we briefly highlight some of these disagreements. We also note that the interpretation of a positive sign on a change in wealth (eg a positive GS) is disputed: this material is also reviewed in this section.

Many authors have commented on how best to value the different components of comprehensive

[46] However, this simple interpretation is not without challenge (Pezzey, 2004).
[47] See Pillarisetti (2005) for a broader criticism of GS.

wealth. These components include natural capital, where the focus is on valuing pollution, resource depletion and changes in ecosystem service benefits; human capital, where the focus is on whether to measure inputs or outputs; and technological change. For natural resource depletion (non-renewable resources such as oil and natural gas, for example), Atkinson and Hamilton (2007) state one approach is changes in the Present Value of net benefits over the lifetime of a resource that should be used to price depreciation. [48] Other authors (eg Hartwick(Hartwick, 1977)) instead use the difference between price and marginal cost as the correct shadow price, although typically this implies that resources are being exploited optimally according to the Hotelling rule. Atkinson and Hamilton (2007) show how different approaches to valuing depreciation depend on a range of background assumptions, including whether the resource is being exploited optimally, and what is happening to marginal extraction costs over time. New discoveries of a non-renewable resource can be included as negative depreciation (eg (Pezzey et al., 2006), whilst capital gains and losses from changes in world prices for net exporters/importers of natural resources can also be accounted for (van der Ploeg, 2011; Vincent, 1997; Asheim, 1986).

For pollution, Hamilton et al. (2006) argued that two conditions were needed for the inclusion of emissions in a GS-type indicator, that either emissions add to a stock of pollution, where it is the stock which reduces the flow of well-being; or that emissions in the current period cause damage to another asset, for example the effects of SO_2 on forest resources, or the effects of particulates such as PM2.5 on human health and thus the ability of workers to be productive. In the former case, the appropriate value for each ton of emissions is the marginal damage cost for that pollutant, or people's willingness to pay to reduce emissions at the margin. (Pezzey et al., 2006) argue that the direct effect of flow pollutants on utility should not be included in a GS-type measure, but only in green GDP account. There has also been dispute over how to include transboundary pollutants in wealth accounts: should they show up in the accounts of the emitter or of the country which suffers damages (Mäler, 1991)? However, in practice many differing approaches have been taken to including or excluding pollution emissions, and these alternatives turn out to have big effects on GS-type measures in some cases (eg (McGrath et al., 2019; Pezzey and Burke, 2014)).

For renewable, living resources such as commercial fisheries and forests, management regimes are far from being economically optimal: fisheries may be over-fished, and forests over-exploited. Moreover, market failure characterises many of the ecosystem services which these assets supply us with. Fenichel and Abbott (2014) were the first to discuss this important problem in wealth accounting, noting that "...despite years of progress (in economics and natural sciences), the value of natural capital remains crudely measured at best". The authors start from the insight that, in dynamic optimisation models of renewable resources, the co-state variable for any stock is a measure of the shadow "in situ" value of one unit of this stock. Such shadow values would fit the bill for wealth accounting. However, such shadow prices need to come from dynamic models which reflect real-world "institutional and social constraints" on resource management – including current policy measures. Human choices over how to manage the natural asset (eg choices over how many fish to catch) depend on both the current stock and these institutional and social constraints. Choices in period t affect the stock in t+1; a shadow price for the stock is then the partial derivative of a discounted welfare (present value) function, which depends on the institutional and social constraints in place, current depletion of the stock, and how this use maps into current and future benefits (ie, the present value of future benefit flows) via ecosystem

[48] This is defined as "...the change in asset value associated with extraction of the mineral over the accounting period" (Atkinson and Hamilton, 2007, p.46).

dynamics and scarcity effects. Measuring how humans respond in their future management of an ecosystem to changes in its condition becomes crucial: at lower stock sizes, leaving one more fish in-situ is increasingly valuable in wealth accounting terms.

Finally, considering there has been much debate about the valuation of changes in human capital. As Hamilton and Liu (2014) point out, human capital apparently accounts for a very large percentage of "missing" assets in the SNA (for higher income countries, they find it accounts for around 60% of total wealth). However, there are two distinct approaches used to calculate changes in human capital in the literature, which might be contrasted as input and output approaches. The former approach (as used in, for example, Greasley et al. (2014)) estimates spending (typically public sector spending only) on education, usually ignoring on-the-job training. The intuition here is that each $ of spending on education adds to the sum of human capital. The latter approach evaluates the discounted life-time earnings of the population (Jorgenson and Fraumeni, 1992); variations over time in the rate of return on education clearly drives a wedge between these two approaches. Hamilton and Liu (2014) also point to the many working assumptions which lie behind using discounted lifetime earnings (as typically measured) and the value of human capital in terms of its ability of a stock to generate well-being over time.

A2 Figures by Region and Income Group

Figure 11 replicates Figure 1 from the main text but breaks the regions into separate graphs. It is clear from this figure that the Middle East & North Africa is one of the most troublesome in respect to conflicting signals from these metrics.

Figure 12 presents the data from Figure 1 broken into income groups. These are presented as separate income groups in Figure 13. Figures 11 and 13 corroborates the findings about regional and income differences reported in Table 4 in the main text.

A3 Growth rates: Averages and end points

As noted in the main text, there is a difference in the data availability from both World Bank (2021) and UNEP (2018a,b).

The World Bank's *CWON* provides annual data from 1995 to 2018, whereas UNEP (2018b) provides data at a quinquennial intervals. Throughout the main text we use average annual growth rates, In this section, we illustrate the same figures as the text using endpoints to calculate growth rates. Firstly, Figure 14 replicates Figure 1 using endpoints to calculate growth rates using a geometric growth rates:

$$Growth\% = ((W_{t+1}/W_t)^{(1/n)}) - 1) \tag{13}$$

In Figure 15 we illustrate wealth per capita growth rates across sub-periods. Surprisingly, of the four time periods presented, the period furthest back in time (1995-2000) shows the greatest correlation (correlation coefficient of 0.374) while the most recent period (2010-2014) has the weakest correlation (correlation coefficient of 0.064).

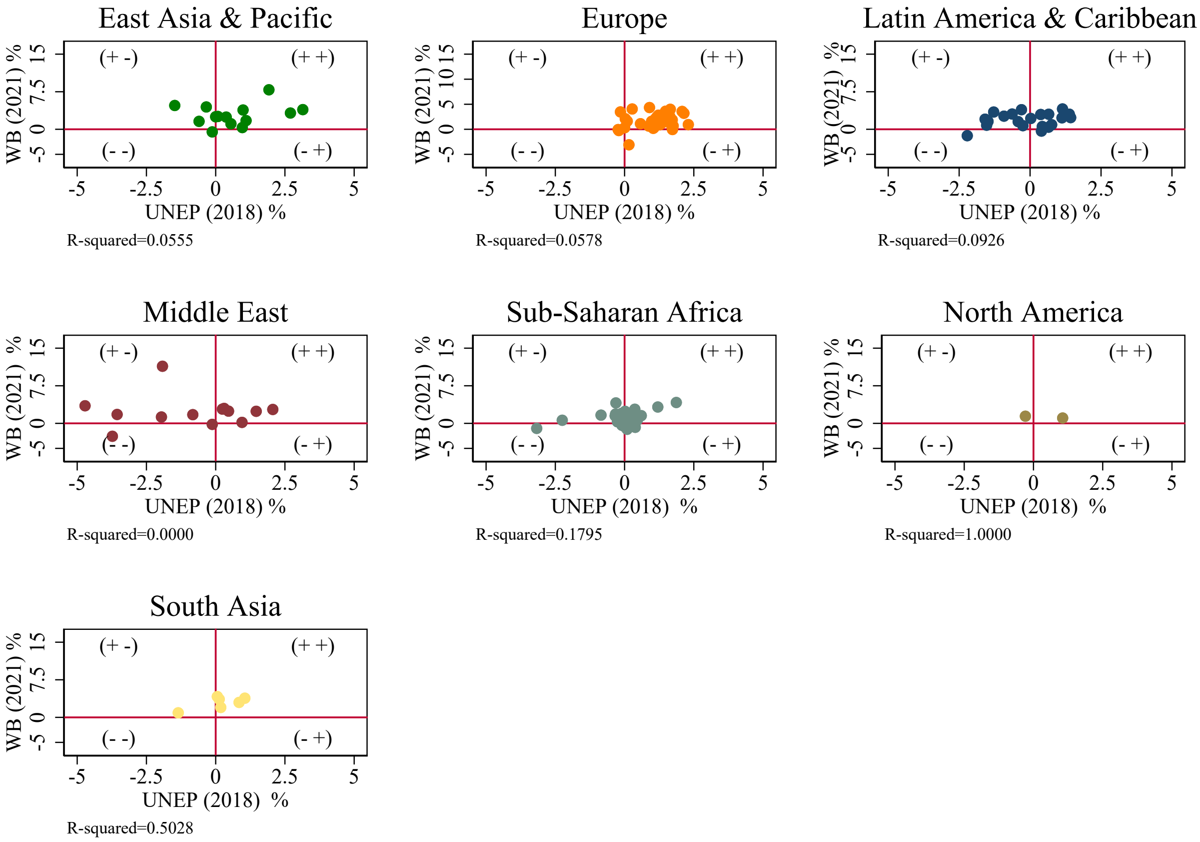

Figure 11: Growth in Wealth per capita by region

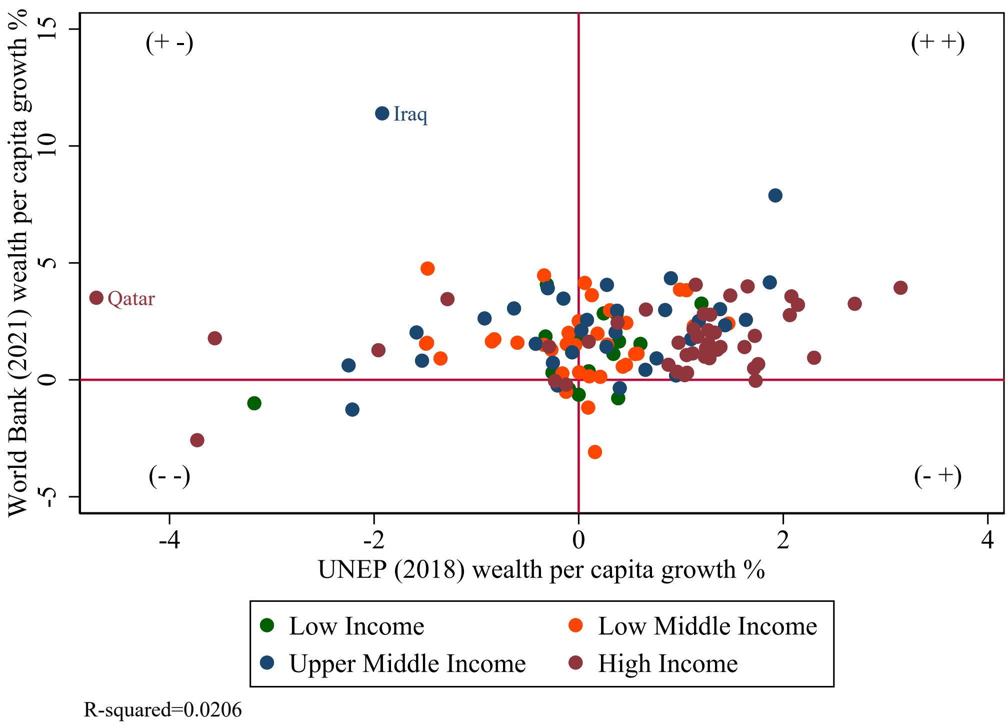

Figure 12: Growth in Wealth per capita by income classification

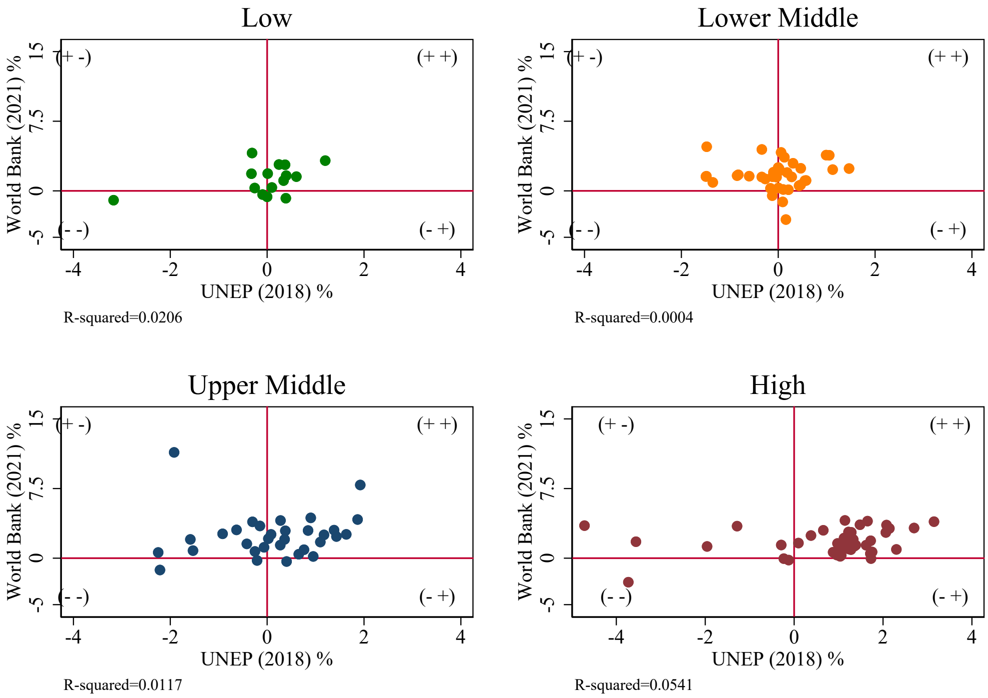

Figure 13: Growth in Wealth per capita by income classification

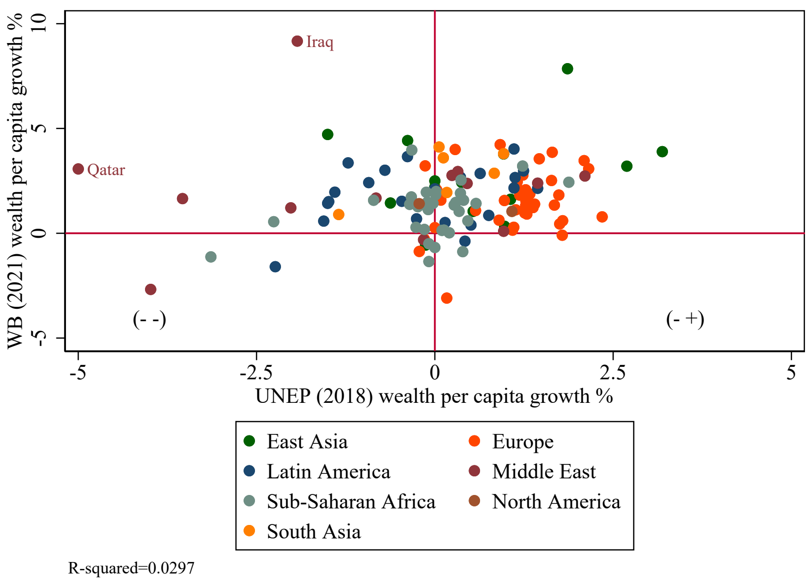

Figure 14: Growth in Wealth per capita (growth rates using end points)

A4 Comparison of Total Wealth

The main text presented all wealth figures as *per capita* growth rates. As Table 1 illustrated, there was a difference between the countries reporting $\Delta W<0$ and $\Delta w<0$. Therefore, distortions may arise from the treatment of population growth. This section looks at the growth in the total wealth and the component series.

Firstly, Figure 16 presents growth in total wealth for both series. While there are fewer countries displaying negative growth, there is considerably variation in the wealth estimates and the reported R-squared is quite low. The correlation coefficient is 0.285, which is higher than the correlation coefficient of 0.144 reported in Table 3.

Figure 17 shows growth rates by sub-period, this should be read in conjunction with Figure 15. While the figures 17 report slightly higher R-squared than in Figure 15, these are still quite low. Again, correlation is strongest in the period 1995-2000 (correlation coefficient of 0.327) with the weakest correlation is for the period 2000 to 2005 (correlation coefficient 0.110).

Figure 18 replicates Figure 5 from the main text, again we see strong correlation in the two estimates of physical capital but the major discrepancies are in terms of the estimates of natural capital (correlation coefficient of -0.05) but less so for human capital (correlation coefficient of 0.429).

A5 Regression results for the full sample of countries

Table 6 reports regression results for the full sample of countries available for CWON, IWR, and GS respectively.

A6 GS per person

GS is usually presented as a share of national income but presenting GS in per capita terms would make it more consistent with the wealth per capita outlined above. Table presents regressions similar to Table from the main text. While results are superficially similar, the main distinction is that the resource rents and regional dummies are insignificant in these regressions. Figure 19 presents scatter plots of GDP % and average GS per capita over the same time horizon.

A7 Comparison between different price deflators

A final point relates to how exactly should the series should be deflated. In essence the answer to this question depends on why we are deflating. If the view is that wealth is essentially a proxy for well-being then a CPI index might be more appropriate, or if we see wealth as the foundation for future income generation than a GDP deflator might be more useful (Inklaar et al., 2023).

Whatever the purpose, while not identical, the CPI & GDP deflators provide good approximations for the other, as shown in figure 20. This is reassuring as both the World Bank (2021) and UNEP (2018a) use GDP deflators.

A8 Comparison between different GDP deflators

Could the divergence be due to how inflation is treated by the respective research groups? World Bank (2022a) reports wealth in constant 2018 US dollars while UNEP (2018a) are reported in "million US

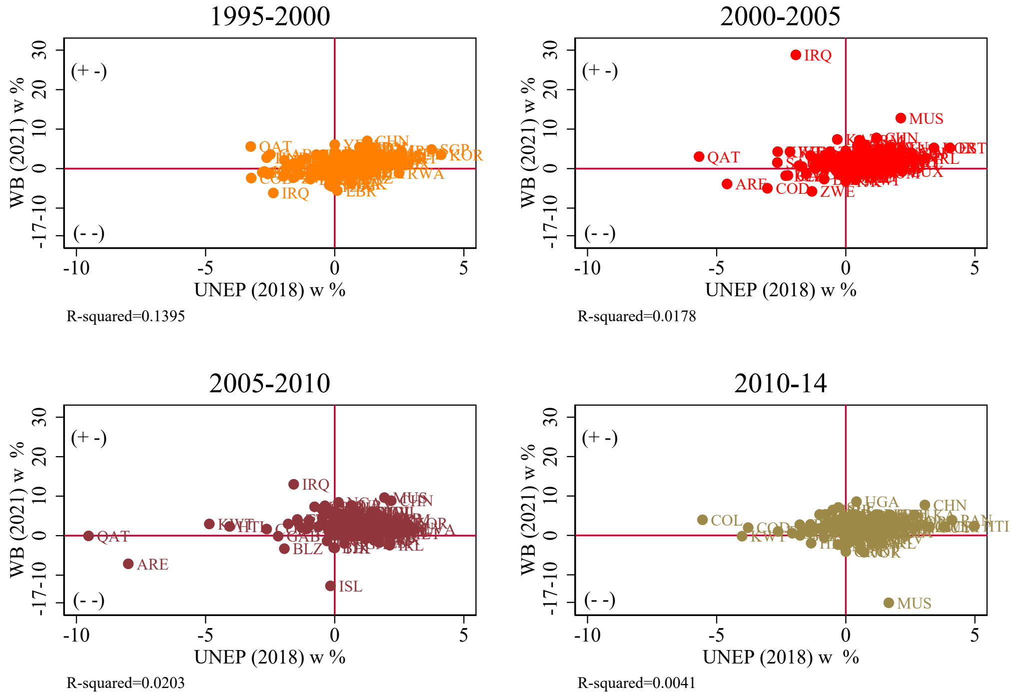

Figure 15: Growth rate in Wealth per capita by sub-period, 1995-2014

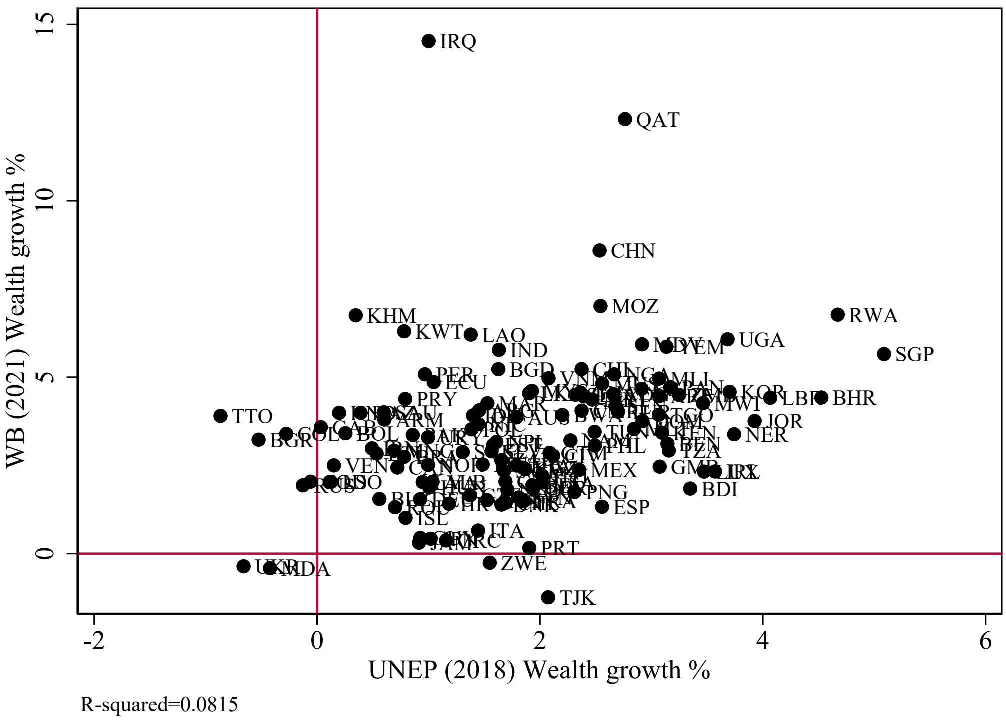

Figure 16: Wealth growth %, 1995-2014

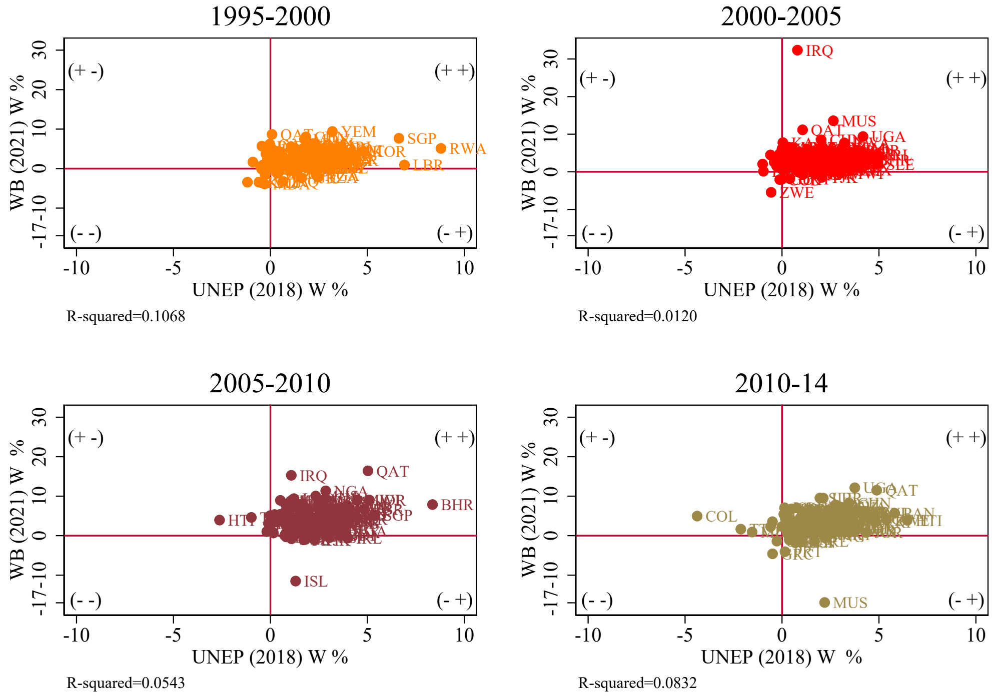

Figure 17: Wealth growth % by subperiods, 1995-2014

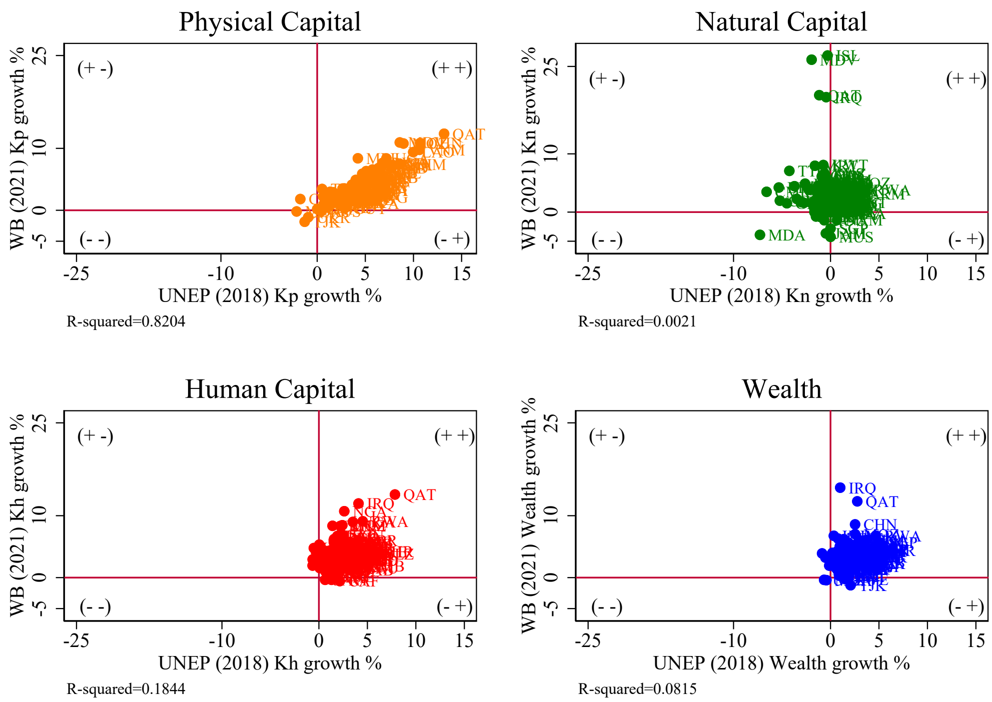

Figure 18: Wealth growth by components %

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δ w (World Bank)			Δ w (UNEP)			Δ W (GS)		
GDP per capita %			0.66***			0.14***			1.00***
			(0.099)			(0.041)			(0.372)
	Resource Rents (share of GDP)								
Minerals		-0.08	-0.11		-0.04	-0.05		0.06	-0.03
		(0.112)	(0.090)		(0.044)	(0.044)		(0.486)	(0.523)
Coal		0.16	0.06		-0.11	-0.12		0.78***	0.71***
		(0.255)	(0.227)		(0.082)	(0.086)		(0.169)	(0.177)
Oil		0.04	0.05**		-0.07***	-0.06***		-0.09	-0.08
		(0.032)	(0.020)		(0.017)	(0.017)		(0.135)	(0.133)
Gas		0.02	-0.02		-0.33**	-0.36**		1.19**	1.18**
		(0.044)	(0.031)		(0.151)	(0.157)		(0.477)	(0.488)
	Income Classification								
Low	0.41	0.68	-0.49	-0.25	-0.52	-0.69*	-12.00***	-12.20***	-13.22***
	(0.614)	(0.687)	(0.491)	(0.448)	(0.382)	(0.380)	(4.082)	(3.993)	(3.986)
Lower-Middle	-0.14	0.04	-0.62	-0.43	-0.45	-0.57**	-6.84***	-8.08***	-9.21***
	(0.513)	(0.569)	(0.400)	(0.366)	(0.292)	(0.281)	(2.496)	(2.626)	(2.618)
Upper-Middle	1.24**	1.17**	0.04	-0.35	-0.25	-0.41*	-3.66*	-3.76*	-5.28**
	(0.585)	(0.584)	(0.349)	(0.296)	(0.226)	(0.213)	(1.958)	(2.049)	(2.098)
High	Reference Group								
	Regions								
EastAsiaPacific	0.87	0.83	0.84**	-0.30	-0.16	-0.24	9.14***	9.48***	10.01***
	(0.655)	(0.672)	(0.364)	(0.340)	(0.320)	(0.302)	(2.455)	(2.435)	(2.380)
Latin America & Caribbean	-0.48	-0.40	0.63*	-0.93***	-0.83***	-0.69***	4.75**	5.52**	7.18***
	(0.564)	(0.587)	(0.376)	(0.279)	(0.236)	(0.221)	(2.146)	(2.191)	(2.292)
Middle East & North Africa	0.39	-0.28	0.54	-1.60***	-0.18	-0.02	9.46***	10.94***	12.28***
	(0.815)	(0.772)	(0.467)	(0.602)	(0.421)	(0.393)	(3.505)	(4.104)	(4.007)
North America	-0.39	-0.38	0.36	-0.79	-0.66	-0.52	-0.69	-1.00	0.04
	(0.286)	(0.293)	(0.249)	(0.508)	(0.408)	(0.403)	(1.568)	(1.450)	(1.578)
South Asia	1.19	1.09	1.17**	-0.54	-0.55	-0.59*	19.04***	20.28***	20.06***
	(0.734)	(0.745)	(0.453)	(0.406)	(0.348)	(0.318)	(3.092)	(3.281)	(3.002)
Sub-Saharan Africa	-0.72	-0.88	0.20	-0.89**	-0.63**	-0.50*	1.93	2.66	4.07
	(0.562)	(0.618)	(0.464)	(0.352)	(0.280)	(0.275)	(3.158)	(3.031)	(3.042)
Constant	1.63***	1.56***	-0.13	1.17***	1.33***	1.00***	8.24***	7.71***	5.20***
	(0.253)	(0.261)	(0.319)	(0.120)	(0.105)	(0.141)	(1.233)	(1.239)	(1.625)
Observations	146	146	146	140	140	140	160	160	160
R-squared	0.14	0.17	0.59	0.25	0.49	0.53	0.27	0.30	0.33
Mean		1.893 %			0.298%			(8.035% of GNI)	
Standard Deviation		1.897%			1.202%			(11.271% of GNI)	

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 6: Regression of changes in wealth, 1995-2014

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.

	(1)	(2)	(3)	(4)	(5)	(6)
		Δ W (GS per capita)			Δ W (GS per capita)	
GDP Growth per capita %			-21.48			-170.28
			(135.231)			(135.028)
			Resource Rents (share of GDP)			
Mineral		-63.97	-62.03		-30.78	-24.02
		(67.951)	(71.829)		(89.731)	(85.860)
Coal		26.88	28.32		-177.50	-153.73
		(27.561)	(29.259)		(236.665)	(242.730)
Oil		27.18	26.97		31.98	28.79
		(27.807)	(27.802)		(41.700)	(41.213)
Gas		290.60	290.90		1,235.39	1,223.89
		(362.733)	(363.649)		(1,204.144)	(1,226.563)
			Income Classification			
Low	-4,312.87***	-4,123.00***	-4,101.12***	-5,232.23***	-5,131.23***	-4,876.47***
	(1,101.397)	(1,105.261)	(1,097.396)	(1,150.917)	(1,275.147)	(1,310.086)
Lower-Middle	-4,418.68***	-4,405.81***	-4,381.54***	-5,297.26***	-5,190.64***	-5,038.97***
	(1,052.555)	(1,108.731)	(1,109.824)	(1,184.019)	(1,190.213)	(1,212.272)
Upper-Middle	-3,032.10**	-3,083.45**	-3,050.64**	-4,381.75***	-4,458.47***	-4,238.33***
	(1,267.182)	(1,316.111)	(1,245.616)	(1,032.893)	(1,084.679)	(1,101.195)
High			Reference Group			
			Regions			
East Asia & Pacific	214.22	273.50	262.10	1,113.74	1,174.93	1,264.43
	(1,123.134)	(1,137.070)	(1,129.542)	(1,080.946)	(1,173.446)	(1,189.740)
Latin America & Caribbean	-865.20	-672.65	-708.30	223.26	361.67	152.99
	(1,180.895)	(1,243.428)	(1,187.980)	(819.891)	(927.779)	(977.875)
Middle-East & North Africa	1,323.96	674.30	645.52	3,414.60	1,581.51	1,505.83
	(1,845.314)	(1,559.975)	(1,589.164)	(2,497.034)	(1,841.274)	(1,884.309)
North-America	-1,218.02	-1,234.26	-1,256.60	-1,095.37	-1,498.41	-1,651.60
	(890.867)	(887.634)	(881.013)	(922.121)	(1,088.156)	(1,101.688)
South-Asia	221.87	333.42	338.15	1,223.63	1,231.46	1,271.94
	(1,095.712)	(1,243.014)	(1,255.595)	(929.722)	(1,024.638)	(1,037.345)
Sub-Saharan Africa	-328.54	-329.55	-359.96	770.73	883.01	671.17
	(1,119.245)	(1,215.115)	(1,194.219)	(920.569)	(1,120.261)	(1,185.543)
Constant	4,587.98***	4,411.53***	4,465.55***	4,465.32***	4,132.68***	4,545.58***
	(877.379)	(886.567)	(919.746)	(908.808)	(889.759)	(1,031.414)
Observations	160	160	160	121	121	121
R-squared	0.23	0.24	0.24	0.34	0.39	0.39
Mean		1839			1889	
Standard Deviation		4175			4001	

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 7: Regression of GS per capita, 1995-2014

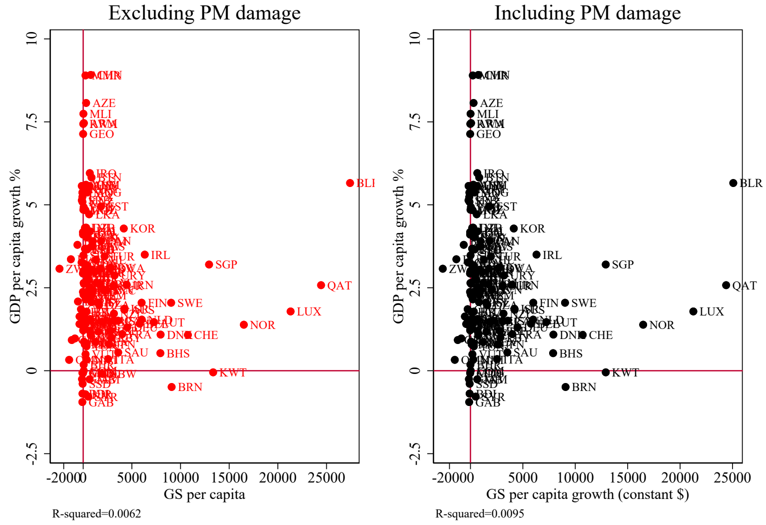

Figure 19: Genuine Savings per capita and GDP per capita growth
Note:GS per capita, deflated using a GDP deflator. Data for GS per capita from World Development Indicators: Series: Adjusted net savings, excluding particulate emission damage (current US$) [NY.ADJ.SVNX.CD]; Adjusted net savings, including particulate emission damage (current US$) [NY.ADJ.SVNG.CD]; Population, total [SP.POP.TOTL]; GDP deflator (base year varies by country) [NY.GDP.DEFL.ZS].

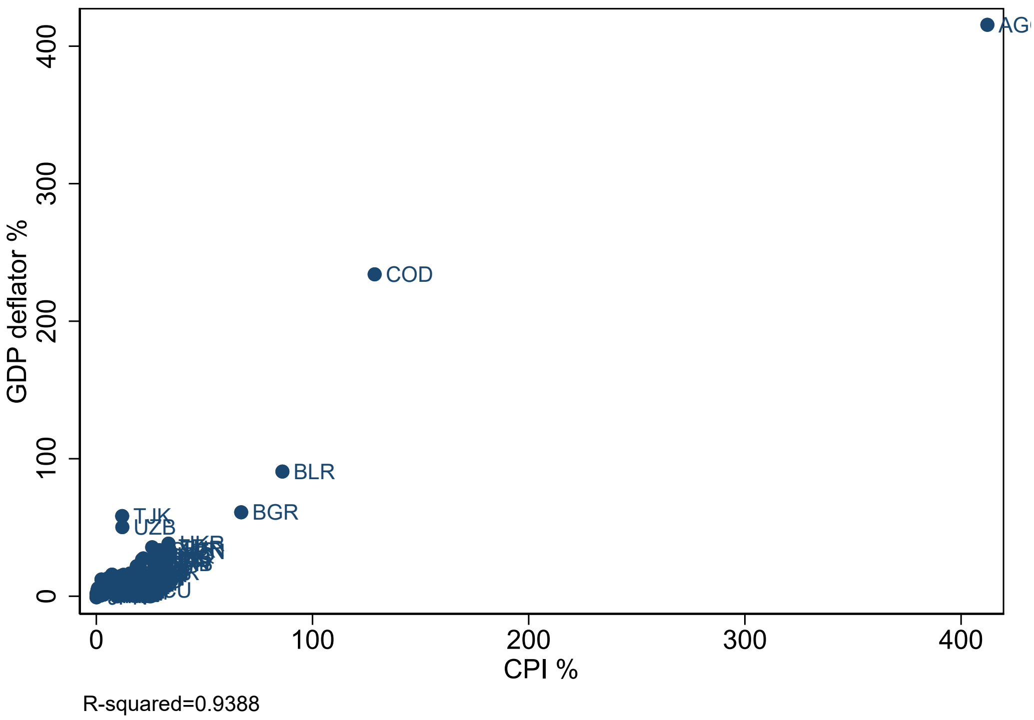

Figure 20: Comparing inflation measures, GDP deflators and CPI (1995-2014)

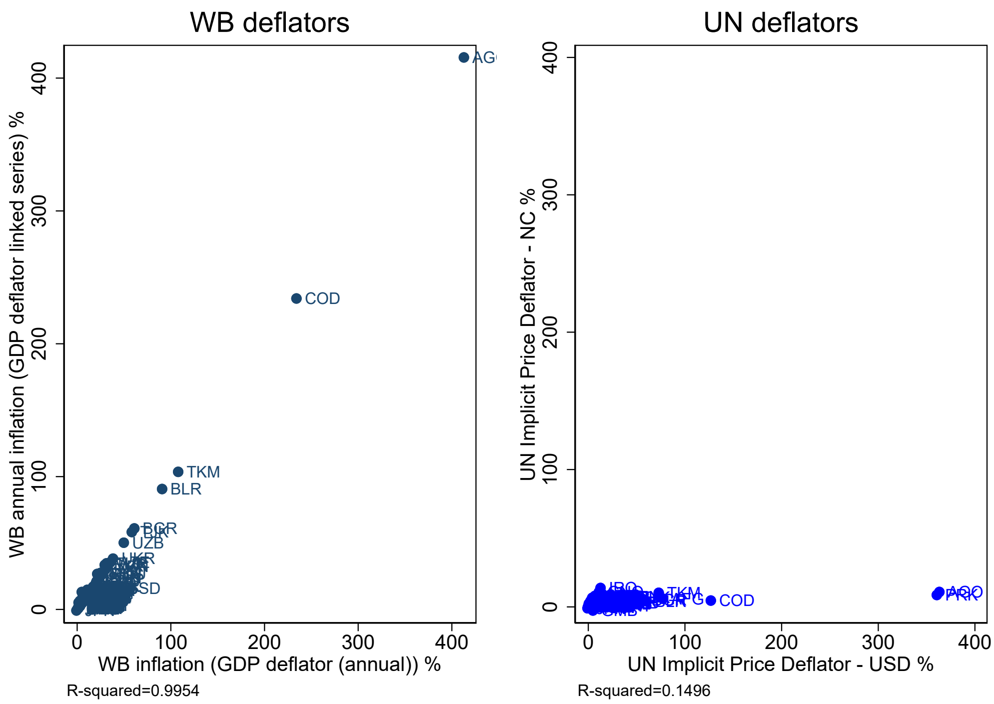

Figure 21: Different GDP deflators from World Bank and UN databases

dollars, 2005". The World Bank research team outline how 'a country specific GDP deflator is used for all natural capital components to bring the nominal values to constant 2018 US dollars at market exchange rates.'

However, it is unclear what deflator was used by the UNEP research team. UN (2023) database reports implicit price deflators in national currencies and in US dollars. If it is the former, then it is almost identical to what is used in the *CWON*, if it is the latter there would be a significant divergence.

To illustrate this point, Figure 21, compares the different GDP deflators for the period 1995-2014 available on the World Bank (2022b) and UN (2023). While a slight difference in methodology for the World Bank (2022b) series in terms of GDP deflators. Series 'NY.GDP.DEFL.ZS', states it is a 'GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency'. Whereas series 'NY.GDP.DEFL.KD.ZG.AD' states that 'this series has been linked to produce a consistent time series to counteract breaks in series over time due to changes in base years, source data and methodologies'. Figure 22 compares the deflators from the respective institutional databases. When they are national currency deflators there is a tight correlation, however when the methodology is a USD deflator this leads to divergent results.

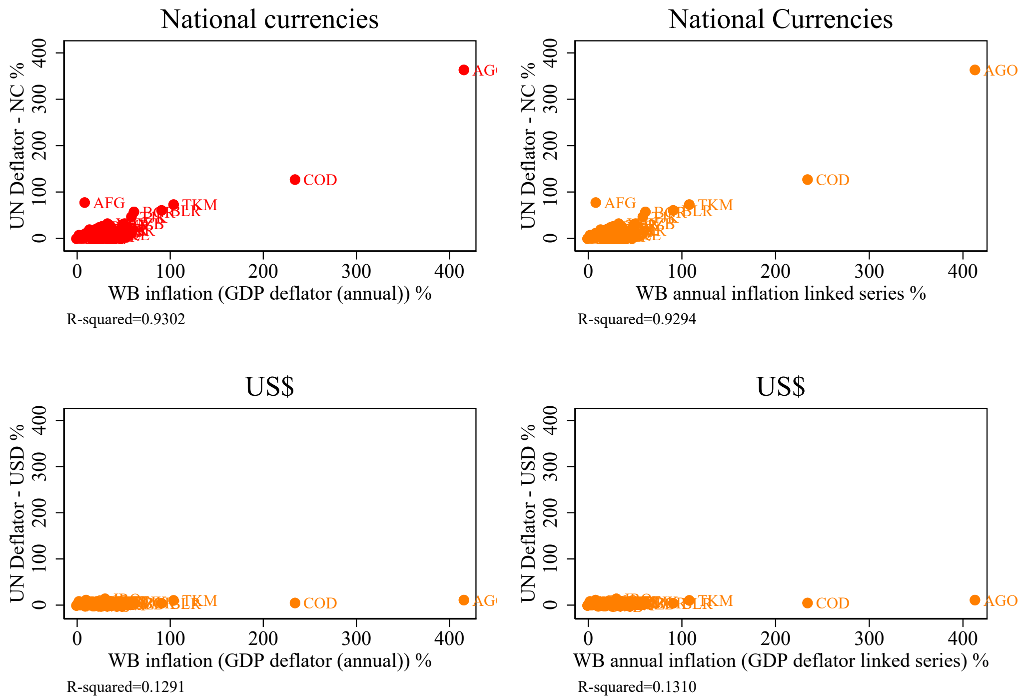

Figure 22: Different GDP deflators