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Sustaining Economic Welfare

Estimating Changes in Per Capita Wealth

Kirk Hamilton

With the notable exception of China, in most countries with below-median per capita income the growth rate of the population is greater than that of total wealth. This trend is ultimately unsustainable. For many of these countries, policies for sustainability will require both boosting savings and slowing population growth.

Summary findings

The World Bank's *World Development Indicators 1999* highlights for the first time the "genuine" rate of saving for more than 100 countries around the globe. Genuine saving values the total change in economic assets, thereby providing an indicator of whether an economy is on a sustainable path.

The Bank's new estimates of genuine saving broaden the usual national accounts definitions of assets to include human capital, minerals, energy, forest resources, and the stock of atmospheric carbon dioxide.

Genuine saving measures the change in total assets rather than the change in per capita assets. Genuine saving data may answer the question, "Did total wealth rise or fall over the accounting period?" But they do not address the question of whether an economy is

sustainable with a growing population. Genuine saving could be positive even though per capita wealth is declining.

Hamilton explores the issue of measuring changes in per capita wealth—factoring in both growth in total assets (as measured by genuine saving) and population growth—as a more comprehensive indicator of sustainability.

First he develops a theoretical approach to estimating total wealth. Then he presents cross-country estimates of changes in per capita wealth.

Based on preliminary estimates, he concludes that in the majority of countries below the median per capita income, wealth is accumulating more slowly than the population is growing.

This paper—a product of the Office of the Director, Environment Department—is part of a larger effort in the department to apply economic approaches to environmental management. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Luz Rivera, room MC5-206, telephone 202-458-2819, fax 202-522-1735, email address lriviera@worldbank.org. Policy Research Working Papers are also posted on the Web at www.worldbank.org/research/workingpapers. The author may be contacted at khamilton@worldbank.org. November 2000. (28 pages)

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Sustaining Economic Welfare: Estimating Changes in Per Capita Wealth

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Introduction

The 1999 publication of *World Development Indicators* (World Bank 1999) highlights for the first time the ‘genuine’ rate of saving for over 100 countries around the globe. As a more-inclusive measure of net saving effort, one that includes depletion and degradation of the environment in addition to the depreciation of produced assets, genuine saving provides a useful indicator of sustainable development. Hamilton and Clemens (1999) show for simple growth models that negative rates of genuine saving imply future declines in welfare along the optimal path for the economy (i.e., unsustainability by Pezzey’s (1989) definition). Dasgupta and Mäler (forthcoming) show that this result carries over to non-optimal development paths for suitable definitions of the accounting prices of assets. In the real world these theoretical results imply the common-sense notion that sustained negative rates of genuine saving must lead, eventually, to declining welfare.

An important point in all of this, of course, is that it is *per capita* welfare that must be sustained. Genuine saving measures the change in total assets rather than the change in assets per capita. While genuine saving is answering an important question, therefore – did total wealth rise or fall over the accounting period? – it does not speak directly to the question of the sustainability of economies when there is a growing population. If genuine saving is negative then it is clear in both total and per capita terms that wealth is declining. For a range of countries, however, it is possible that genuine saving could be positive while wealth per capita is declining.

A simple formula makes this clear. Assuming that total wealth is not explicitly a function of population², then for total wealth K and population P it follows that,

$$\Delta\left(\frac{K}{P}\right) = \frac{K}{P}\left(\frac{\Delta K}{K} - \frac{\Delta P}{P}\right), \quad (1)$$

where Δ represents the change in a variable over the accounting period (ΔK is therefore genuine saving, while ΔP is the total change in population). If the percentage change in total wealth is less than the percentage growth in population, total wealth per capita will fall.

The practical difficulty with expression (1) is that there are no widely available statistics on total wealth. Many (but not all) OECD countries publish national balance sheet accounts, which measure the total value of produced assets and commercial land. Virtually no developing countries publish these accounts. Moreover, to be useful as a sustainability indicator, the total wealth figures employed in expression (1) must be very broad, encompassing produced assets, commercial land, natural resources, and human and social capital. In *Expanding the Measure of Wealth* (World Bank 1997; see Kunte *et al.* 1998 for details) such a broad wealth measure was estimated for roughly 100 countries for 1994. However, these estimates are expensive to produce and are unlikely to be updated frequently³.

² Atkinson *et al.* (1997) derive the more general expression when total wealth is a function of population.

³ The genuine savings estimates published by the World Bank are kept up to date, but conceptual differences with the wealth estimates preclude simply updating the 1994 wealth estimates by accumulating the annual levels of genuine saving.

This paper will develop a conceptually sound approach to total wealth estimation, with the specific goal of estimating changes in wealth per capita. The analysis proceeds by presenting a formal model, followed by a detailed exposition of methodology using the United States as an example, followed by a presentation of results for 110 countries.

A Formal Model for Wealth Estimation

The System of National Accounts (SNA) approach to wealth measurement, and the approach adopted in part in *Expanding the Measure of Wealth* (World Bank 1997), is generally to place an economic value on individual assets and to add up the resulting values. In the realm of tangible assets this makes eminent sense, but this presents problems to national accountants when assets are intangible. Moreover, it can be argued that the most important assets – human health, knowledge and skills, creativity, institutional and social capital – are precisely the least tangible.

The alternative to valuing and summing individual assets is to think more broadly about what we mean by wealth. The economist's answer to this question is clear: a useful measure of wealth would capture the *consumption possibilities* for the economy going forward. At the broadest, consumption should include not only ordinary goods and services, but the value consumers place on a variety of non-market flows of benefits as well (a beautiful view over a pristine environment, for example). However, in this context it is important to distinguish only those benefits that are not reflected in other market values measured in the national accounts.

The other issue in measuring wealth is to carefully distinguish consumption from investment. Ordinary national accounting treats as consumption many items that are, by their nature, clearly investments. The key examples of this are net health investment (expenditures producing long term increases in healthfulness), education expenditures, and outlays on research and development.

The simplest formal model available to deal with the question of wealth measurement is the Solow growth model. Assume there is a homogenous good that may either be consumed C or invested in capital K , and which is the output of a production function $F(K)$. Assume as well that population P grows exogenously at some fixed rate g . Then for *per capita* consumption c and capital k , the economic goal is to maximize the utilitarian maximand V as follows:

$$\max V_t = \int_0^{\infty} U(c(s), b(s)) e^{-\delta(s-t)} ds \quad \text{subject to} \quad \dot{k} = F(k) - c \quad \text{for fixed rate of time preference } \delta.$$

Note that the utility function for the 'representative individual' includes other per capita flows of benefits b in addition to those from consumption (this could include the benefits from environmental amenities, for example). Capital should be conceived very broadly to include natural resources, knowledge, skills, creativity and institutional and social capital.

The Hamiltonian function for this problem is given by $H = U + U_c \dot{k}$, while the efficient path for the marginal utility of consumption is described by:⁴

$$\frac{\dot{U}_c}{U_c} = \delta - F' \Rightarrow \delta + \eta(c) \frac{\dot{c}}{c} = F'. \quad (2)$$

Here $\eta(c)$ is the elasticity of the marginal utility of consumption. The right-hand portion of expression (2) serves to define the consumption rate of interest: the sum of the pure rate of time preference and the product of the elasticity of the marginal utility of consumption and the percentage growth rate of per capita consumption. In this idealized economy, with no risk or taxes, the consumption rate of interest is identically equal to the marginal product of capital.

From the left-hand portion of expression (2) it follows that, for $s > t$,

$$U_{c(s)} = U_{c(t)} e^{\delta(s-t) - \int_t^s F'(k(\tau)) d\tau} \quad (3)$$

It is a general property of these equation systems that,

$$H = U + U_c \dot{k} = \delta V \Rightarrow U_c \dot{k} = \dot{V}. \quad (4)$$

Applying expression (3) and integrating the right-hand portion of expression (4) yields (up to a constant of integration),

$$k = \int \frac{U}{U_c} e^{-\int_t^s F'(\tau) d\tau} ds. \quad (5)$$

This is the desired result: a suitably expansive measure of wealth per capita is approximately equal to the present value of consumption per capita, where the discount rate is defined by the consumption rate of interest and consumption may include non-market benefits valued at marginal willingness to pay. In general, assuming non-increasing returns to scale in the utility function and declining marginal utility with respect to consumption and other benefits leads to the result that,

$$U \geq U_c c + U_b b,$$

which in turn implies that,

$$\int c \cdot e^{-\int_t^s F'(\tau) d\tau} ds \leq k - \int \frac{U_b}{U_c} b \cdot e^{-\int_t^s F'(\tau) d\tau} ds.$$

⁴ Dasgupta and Mäler (forthcoming) show that the results in this section hold for any arbitrary development path as long as the same efficiency condition for the marginal utility of consumption holds along the path.

Here U_b/U_c is the marginal willingness to pay for a unit of benefit b . Under plausible assumptions about the utility function, therefore, the present value of consumption per capita is a lower bound for total wealth per capita.

The empirical issues in wealth estimation can be explored through the simple case where consumption per capita c grows at a fixed rate r and where the elasticity of the marginal utility of consumption η is also assumed to be fixed. Then,

$c = c_0 e^{rt}$, so that,

$$k = \int_0^\infty c_0 e^{-(\delta + (\eta-1)r)(s-t)} ds = \frac{c_0}{\delta + (\eta-1)r}.$$

This estimate of wealth is feasible if $\eta > 1 - \delta/r$, and so if $r > \delta$ there is a positive lower bound on η .

As expected, $\partial k / \partial \delta < 0$, so that wealth declines as the pure rate of time preference increases. However,

$$\frac{\partial k}{\partial r} < 0 \text{ if } \eta > 1.$$

If the elasticity of the marginal utility of consumption is larger than 1, the result is that total wealth is a declining function of the growth rate in per capita consumption – the intuition behind this, of course, is that declines in marginal utility more than offset the effects of growth. If $\eta = 1$, then k is independent of r .

The case for wealth per capita as a sustainability indicator rests on the right hand portion of expression (4). If the change in wealth per capita is negative, then the present value of welfare also declines, which in turn implies that the development path is not sustainable. Note that,

$$\dot{k} = \frac{d}{dt} \left(\frac{K}{P} \right) = \frac{K}{P} \left(\frac{\dot{K}}{K} - \frac{\dot{P}}{P} \right) = \frac{K}{P} \left(\frac{\dot{K}}{K} - g \right).$$

This just restates expression (1) in continuous time. $\dot{K}$ is genuine saving.

This model can be made more elaborate, by including a range of natural resources, pollution stocks, notional asset values for R&D and human capital, and so on. But these elaborations would yield little that is new, in the sense that a variation on expression (5) will continue to hold: the sum of these appropriately priced assets would still equal the present value of an expanded consumption measure, discounted at the consumption rate of interest. Appendix 1 derives this result formally for an economy with exhaustible resources and exogenous technical change.

One test of the robustness of this consumption-based approach to estimating wealth is to test whether the cumulative value of genuine saving over some period of time equals the wealth estimate derived from per capita consumption. Appendix 2 shows this to be approximately true, with consumption-based wealth estimates for low income countries exceeding cumulative genuine saving by 5% over a 10 year span.

Detailed Methodology Applied to the United States

Both informal thinking about wealth and the formal growth model suggest that a good estimate of wealth can be provided by the present value of forecasted consumption per capita. However, constructing such a wealth estimate necessarily involves combining a large number of assumptions. What follows is an exposition of these assumptions and a sensitivity analysis of the wealth measures derived therefrom, using US data for 1997 as an example. All data are taken from *World Development Indicators 1999* (hereafter WDI).

As suggested by the formal model, the approach to wealth estimation is to construct an estimate of the present value of consumption. The appropriate discount rate for this calculation is the consumption rate of interest. Many of the key steps in deriving the estimate pertain to careful consideration of what is truly consumption, and what investment. The consumption and genuine saving figures are then adjusted to reflect these considerations, leading to the calculation of estimated wealth. For consumption C as measured in the SNA, adjusted consumption C^* , genuine saving G , and total wealth K , the calculation proceeds as follows:

$$G = GDP - C - \text{Depreciation} - \text{Depletion} + \text{Education} + \text{HealthInvest} + R\&D$$

$$C^* = C - \text{Education} - \text{HealthInvest} - R\&D$$

$$K = \sum_{t=0}^{24} \frac{C^* (1+r)^t}{(1+i)^t}$$

Here i is the consumption rate of interest, while r is the rate of growth of per capita consumption. These estimates are then plugged into expression (1), along with the percentage growth in population, to yield the change in wealth per capita.

Note that genuine saving as defined in WDI differs from ordinary net saving by the amount of depletion of natural resources and education expenditures (the latter are added, as an estimate of investment in human capital). The extended notion of genuine saving defined above includes two additional investment terms. Research and development ($R\&D$) is clearly investment rather than consumption – the System of National Accounts (United Nations 1993) recognizes this, but expresses doubt about the practitioner's ability to estimate the value of the accumulating stock of knowledge and technique. Gross investments in health (reproductive health, post-natal care, vaccinations, and so on) can be considered to be investments to the extent that they add to long run healthfulness, rather than providing pure consumption benefits or maintaining a given level of health. Grossman (1972) makes the point that investment in

healthfulness adds to both expected wages and to the enjoyment of illness-free time for other valued pursuits.

Table 1 lays out the key variables for the wealth estimate and a series of variants on this estimate. Alternative values for the components of the consumption rate of interest are compared to a study for the UK by Pearce and Ulph (1999). Notes on each element of the table follow:

Health investment / capita. The US spent roughly \$4,100 per capita on health care in 1997 and it can be argued that a substantial proportion of this was consumption rather than investments in human capital. The assumed value of \$250 per capita as investment is roughly equal to per capita spending in upper middle income countries, as reported in WDI. *Variant A* looks at the effect of an assumed per capita health investment of \$500.

Consumption / capita. This is the national accounts figure for public and private consumption, adjusted as follows. First, education expenditures (5.8% of GDP) are subtracted from consumption (they are already included in genuine saving). Next, R&D expenditures are apportioned to investment (0.5% of GDP), and public and private current expenditures (1.0% of GDP each). Total current expenditures on R&D are added to genuine saving, while current public expenditures are subtracted from consumption – this treatment reflects the fact that private expenditures on R&D make up a portion of intermediate, as opposed to final, consumption. As just noted, health investments are subtracted from the national accounts measure of consumption and added to genuine saving.

Table 1. Central wealth estimate and variants, United States, 1997.

	Central	A	B	C	D	E
Health investment / capita	\$250	\$500	\$250	\$250	\$250	\$250
Consumption / capita	\$22,300	\$22,000	\$22,300	\$22,300	\$22,300	\$22,300
Genuine saving / capita	\$3,900	\$4,100	\$3,900	\$3,900	\$3,900	\$3,900
Consumption growth / capita	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%
Rate of time preference	1.5%	1.5%	1.2%	1.5%	1.5%	1.5%
Elasticity of MUC	1.0	1.0	1.0	0.8	1.0	1.0
Consumption rate of interest	3.4%	3.4%	3.1%	3.0%	3.4%	3.4%
Population growth rate	0.8%	0.8%	0.8%	0.8%	1.0%	0.8%
Lifetime (for PV)	25	25	25	25	25	30
Wealth / capita	\$462,000	\$456,000	\$479,000	\$485,000	\$462,000	\$535,000
Change in wealth / capita	\$322	\$612	\$190	\$145	(\$742)	(\$243)
Change %	0.07%	0.13%	0.04%	0.03%	-0.16%	-0.05%

Source: author's estimates. MUC: marginal utility of consumption. Figures are rounded.

Genuine saving / capita. Net domestic saving is adjusted to reflect natural resource depletion⁵, CO₂ damages and investments in education. The adjustments and reclassifications mentioned under 'consumption / capita' above are then applied to arrive at an extended measure of genuine saving.

Per capita consumption growth rate. This is the average growth rate of private consumption from 1980 – 1997.

Rate of time preference. This is the pure rate at which people discount future welfare. Estimates for the UK in Pearce and Ulph vary from 0 to 1.7%, with their 'best' estimate being 1.4%. The central assumption here is 1.5%, with *Variant B* reflecting the effects of an assumed level of 1.2% for this variable – this is the median figure estimated by Lawrance (1991) using panel data of US income data covering 1967-71.

Elasticity of the marginal utility of consumption. Pearce and Ulph report UK values in the range of 0.7 to 1.5, with a best estimate of 0.8. The central value used here is 1.0 (which renders the calculation insensitive to the consumption growth rate), while *Variant C* sets the MUC to 0.8.

Population growth rate. Population growth of 0.8% per year is the average of the observed rate over 1980 – 1997 and the projected rate from 1997 – 2015 as reported in WDI. This serves as a 'neutral' estimate of current population growth rates. *Variant D* uses a rate of 1%, which is the observed growth rate over 1980 – 1997.

Lifetime over which the present value is calculated. The central value used is 25 years, while *Variant E* uses a value of 30 years.

Discussion

There is a clear sensitivity of the change in wealth per capita to the population growth rate. The results in Table 1 suggest that US growth in wealth per capita is on a knife edge – if population growth does not slow as assumed in the population projections, then wealth per capita (Variant D) could actually be marginally declining. This may appear to be surprising, given the recent performance of the US economy, but it simply reflects the interplay between a relatively weak savings effort and sizeable population growth. In the case of the US, foreign borrowing has arguably helped finance an extraordinarily productive capital stock, supporting the observed levels of consumption. But the fact that the current account deficit has been between 1 and 3 percent of GDP continuously since 1982 suggests that there are bills to be paid.

On the question of health investment expenditures, it would be valuable to dig more deeply into health data in order to arrive at a defensible measure of primary health care spending. Figures higher than \$250 per capita per year appear questionable, however – World Bank (1993) estimates that \$12 / capita / annum is the expenditure required to supply minimum preventative and essential clinical services in developing countries.

⁵ The resources covered include oil, natural gas, coal, bauxite, copper, iron, lead, nickel, phosphate, tin, gold, silver and timber (net depletion). Soil degradation, subsoil water and fisheries are excluded for reasons of data availability.

Gates (1984) attempts to derive an estimate of gross investment in health in the United States by separating expenditures into those which increase healthfulness over the long term and those which maintain or restore health to a previous state. This overstates the net investment in health because of the difficulty of separating out expenditures on treating injuries, for example, which clearly fall into the category of restoring a state of health. The figure Gates derives for 1978 is roughly \$350 per capita, or 40% of total health expenditures. This may argue for a figure greater than the \$250 used here, but it is highly likely that the proportion of net health investment in total expenditures is much lower than 40% in 1997.

The elasticity of the marginal utility of consumption can be interpreted as a measure of aversion to consumption inequality (either between social groups or across time). The central figure of 1.0 implies that, for two households with consumption varying by a factor of two, the utility provided by an extra dollar of consumption is twice as high in the low-consumption household as in the high. This is a fairly egalitarian assumption. It is difficult to argue for higher (more egalitarian) values of the elasticity of MUC and, moreover, this would lead to the perverse result highlighted in the preceding section, where higher growth rates in per capita consumption would lower the estimated wealth. Lower values of the elasticity of MUC lead to higher wealth estimates, as seen in Variant C.

The question of the lifetime over which to calculate present values has no obvious 'right' answer. The formal model suggests taking the present value to infinity, but it is implicitly assuming infinitely-lived assets as well. The central value, 25 years, corresponds roughly to the length of a human generation and to the service life of relatively long-lived produced assets. Any argument for longer lifetimes will clearly tend to increase estimated wealth and decrease the change in wealth per capita.

Is \$462,000 a reasonable estimate of per capita wealth? One test is to calculate the implicit rate of return in the economy. GDP can be considered to be the rate of return on total assets in an economy – a minor extension of the growth model presented above provides the theory to back up this common-sense notion. For the US per capita GDP of \$29,271 in 1997, the implied rate of return on total wealth (i.e., dividing by \$462,000) is 6.3%. This is very much in line with long run real rates of return on assets in the US economy.

For countries with large immigrant and emigrant populations, as in the US, there may at first glance be an issue for the wealth calculation concerning the amount of human capital that is crossing the borders each year. However, it is reasonable to assume that observed consumption rates per capita reflect the cumulative effect of migration of human capital – the large immigration of skilled technology workers to Silicon Valley, for example, presumably has boosted aggregate consumption and therefore estimated wealth in the US. A 'brain drain' would have the opposite effect.

Aside from the variables affecting the wealth calculation, it is worth commenting on the genuine saving estimates as well. As reported in the WDI, there is reason to believe that depletion of exhaustible resources is overstated by the chosen methodology of estimation. On the other hand, there are three gaps in coverage which imply that genuine saving is over-stated. First,

human capital is not depreciated in the World Bank estimates. Second, local pollution damages are not calculated – this is likely to be particularly serious for pollutants such as particulate matter (PM10) and SOx. Finally, depletion of resources such as agricultural soils and fisheries do not appear in the genuine saving estimates owing to data limitations. On balance, genuine saving may be over-estimated by several percent of GDP in many countries.

Cross-Country Wealth Estimates

To examine the question of changes in wealth per capita across the globe, the wealth estimation methodology of the previous section, including central values of all parameters and capping primary health care expenditures at \$250 per capita, was applied to 110 countries – these represent the countries for which sufficient data are available from WDI. Table A1 at the end of this paper presents the results for all countries for 1997. The remainder of this section summarizes the information in Table A1 in order to shed further light on these results.

Alternative estimates of changes in wealth per capita are shown in Table 2. The first columns summarize the results by nominal income (GDP per capita) deciles for all countries using a constant pure rate of time preference (RTP) of 1.5%. It is reasonable to assume that poorer countries in fact have higher rates of time preference – this would be consistent with the generally lower saving rates in poor countries – but there appear to be no cross-country estimates of RTPs for developing countries in the literature. A rough approximation to income-dependent RTPs is therefore derived from the Lawrance (1991) panel study using US income data. Lawrance finds that RTP varies by a factor of 2.44 from the first decile to the tenth (from 2.2% to 0.9% with a median, as noted earlier, of 1.2%). This same ratio is then applied to cross-country income deciles to arrive at the ‘central’ wealth estimates reported in the middle columns of Table 2 (this corresponds to RTP varying from 1.5% in the highest decile to 3.66% in the lowest, with equal steps in RTP across deciles). Because the variation in income deciles across countries is higher than for US income groups (cross-country income deciles vary by a factor of 35 in purchasing power parity (PPP) terms), a third variant is summarized in the final two columns of Table 2, corresponding to a maximum RTP of 5% in the lowest income decile.

Table 2. Wealth per capita and percentage change by income deciles, 1997.

	RTP = 1.5%		Central estimate RTP → 3.66%		RTP → 5.0%	
	Wealth / capita \$	Change in wealth / capita	Wealth / capita \$	Change in wealth / capita	Wealth / capita \$	Change in wealth / capita
1	3300	-2.19%	2600	-2.08%	2200	-2.01%
2	5300	-1.96%	4300	-1.90%	3800	-1.86%
3	6200	-1.02%	5100	-0.86%	4600	-0.75%
4	8500	2.00%	7200	2.55%	6500	2.92%
5	17500	-0.52%	15200	-0.35%	14000	-0.24%
6	31600	0.04%	28200	0.22%	26400	0.33%
7	43800	0.09%	40200	0.16%	38200	0.21%
8	65600	-0.04%	62000	0.05%	59900	0.10%
9	211900	0.30%	210300	0.31%	209400	0.31%
10	414100	0.70%	414100	0.70%	414100	0.70%

Rates of time preference of 3.66% or 5% represent very high rates of impatience, and it is not clear that detailed study of time preference rates in developing countries would bear out these assumed rates. Nevertheless, the conclusion from Table 2 is that the broad result, negative changes in wealth per capita in the five lowest income deciles, is robust for varying rates of time preference. There is only one sign change, for decile 8, and it is small. China with its enormous size and robust savings rate completely dominates the result for decile 4 – if China is dropped from the sample then the central estimate displays the changes in decile wealth per capita shown in Figure 1, while the mean wealth per capita in decile 4 rises to \$10,700 (all wealth figures are rounded to the nearest \$100 in what follows).

Figure 1. Change in wealth per capita by income decile, 1997, excluding China.

These results can be compared with the 1994 total wealth estimates published in *Expanding the Measure of Wealth* (EMW) (World Bank 1997) and detailed in Kunte *et al.* (1998). While the methodological emphasis in this earlier work was on detailed estimation of natural resource wealth for roughly 100 countries, the total wealth estimates were dominated by 'human resources' as an asset class, constituting over 60% of the wealth of most nations. The value of human resources was estimated as a residual by eliminating the returns to natural resources and produced assets from GNP; this residual was then valued at PPP exchange rates and converted to a stock by taking the present value of this flow over the remaining years of life of the population (life expectancy at age one capped at 65 years, minus the mean age of the population) using a social discount rate of 4% for all countries.

Figure 2 scatters the consumption based wealth estimates (for constant RTP of 1.5% and converted to PPP dollars) against those for 1994 in EMW. The fitted line has a slope of 0.95 (to be expected since nominal wealth in 1994 is being compared with that in 1997) and an R^2 of 0.96. Some notable outliers aside, there is clear comparability of the results. Not too much should be made of this similarity, however, given the dominance of the human resources asset class in the EMW estimates.

Figure 2. Consumption based wealth estimates compared with *Expanding the Measure of Wealth*.

To give some idea of the range in the wealth estimates, Table 3 summarizes the results on changes in wealth per capita for the highest and lowest 10 countries appearing in Table A1⁶. Note that Saudi Arabia has been eliminated from the lowest 10, owing to the likelihood of a large under-estimate of genuine saving in this country, while Botswana has been eliminated from the highest 10 because of the lack of data on diamonds (and the corresponding over-estimate of genuine saving).

⁶ Table A1 and all of the results to follow pertain to the 'central' wealth estimate described in Table 2.

Table 3. Low and high growth in wealth per capita, 1997.

	GDP / capita \$	GDP growth rate 1990-97, %	Population growth rate %	Genuine Saving % of GDP	Wealth / capita \$	Change in wealth / capita, \$	Change in wealth / capita, %
Nigeria	338	2.8	2.7	-10.4	4300	-152	-3.5
Jordan	1581	6.3	3.3	4.6	23800	-707	-3.0
Mauritania	446	4.2	2.5	-5.0	6100	-178	-2.9
Gambia, The	345	2.2	2.9	0.3	5000	-145	-2.9
Niger	189	1.5	3.2	6.0	2700	-76	-2.8
Chad	224	4.6	2.7	-0.8	3500	-97	-2.8
Azerbaijan	579	-15.1	1.0	-25.8	8600	-234	-2.7
Malawi	245	3.6	2.6	-0.9	3600	-96	-2.7
Sierra Leone	173	-4.4	2.1	-9.3	2800	-74	-2.7
Syrian Arab Rep	1202	6.3	2.7	0.5	15600	-415	-2.7
Slovak Republic	3615	0.6	0.3	23.6	41300	730	1.8
Malaysia	4545	8.6	2.1	36.3	42300	749	1.8
Thailand	2540	7.4	1.1	30.7	27100	481	1.8
Czech Republic	5050	-0.2	-0.1	20.9	60000	1097	1.8
Korea, Rep.	9622	7.2	0.9	32.1	113900	2091	1.8
Panama	3032	4.8	1.6	36.9	32300	600	1.9
Ireland	20494	7.0	0.5	31.3	254300	5027	2.0
Hungary	4503	-0.2	-0.3	29.4	54600	1491	2.7
Singapore	31036	8.5	1.4	41.7	290900	8942	3.1
China	735	11.6	1.0	38.0	6800	212	3.1
Avg (110 countries)					72900		-0.1

Note: Saudi Arabia and Botswana have been omitted from this table.

The countries with the greatest percentage loss in wealth per capita in Table 3 are from sub-Saharan Africa and the Middle East, with Azerbaijan as the lone Central Asian example (owing to a weak saving effort and substantial depletion of oil resources). The countries with the greatest percentage increase are in East Asia and Central Europe, with Ireland standing out as the lone high income OECD country. Note that the genuine savings numbers in this table, and in Table A1, differ from those published in WDI because of the further adjustments made for health and R&D investments.

Four of the negative wealth growth rate countries in Table 3 have positive genuine savings rates, which relates to the question posed at the beginning of this paper: tracking changes in total wealth through genuine saving may not reveal an underlying decline in wealth per capita. Figure 3 provides a more comprehensive view of this phenomenon.

Figure 3. Relationship between genuine saving and change in wealth per capita.

The upward slope of the scatter in Figure 3 is unsurprising. The lower-right quadrant of the figure suggests that there are many countries with positive genuine saving but declining wealth per capita. Broadly speaking, genuine saving rates of less than 10% of GDP entail a very high likelihood of declining wealth per capita, while rates in excess of 25% are generally associated with increasing wealth per capita. For genuine saving rates in between these limits, the results are highly variable and, presumably, specific to country conditions.

Less apparent in Table 3 is the variation in growth rates of wealth per capita with population growth rates. This is displayed in Figure 4.

Figure 4. Relationship between growth rates of wealth per capita and population.

As expected, this relationship is negative. The elasticity of 1.23 suggests that there is a tendency for genuine saving to vary negatively with population growth. For population growth rates in excess of 1.20% there is a high likelihood of negative growth in wealth per capita.

The final points to note from Table 3 concern the average for wealth per capita and its growth for all 110 countries in the sample. The average wealth per capita, \$72,900, is higher than the value for the 8th decile in Table 2 – the wealth distribution is highly skewed, in other words. Secondly, the average change in wealth per capita is marginally negative. Across the world, these results suggest that aggregate wealth is growing slightly more slowly than total population.

In terms of the individual country results in Table A1, a few results are worth commenting upon. As noted earlier, Botswana tops the list in terms of growth in wealth per capita, but this is overstated because, owing to data limitations, there is no depletion of diamonds in the genuine saving calculation. Other notable African countries are Ghana and Uganda at -2.2%, and South Africa at -0.7%. The Latin American giants, Brazil, Mexico and Argentina, all display minor declines in estimated wealth per capita. Several Eastern European countries show increasing wealth per capita, such as Bulgaria and Estonia at 1.5%, but this is partly due to declining population. Along with Ireland, the other high-income OECD country to stand out is Australia, with its moderate decrease in wealth per capita – this reflects low savings, high mineral depletion and relatively large population growth.

Tables A2 and A3 attempt to 'bracket' the wealth estimates by answering two questions. First, taking observed genuine saving as given, what is the level of wealth that would be consistent with 0 change in wealth (this is referred to as the 'break-even' level of wealth in Table

A2)? Second, taking the estimated wealth as given, what is the level of genuine saving that would be consistent with 0 change in wealth? – this leads to the notion of a ‘savings gap,’ the difference between break-even genuine saving and its observed level. Algebraically these calculations are as follows:

Table A2: For *given* ΔK , ΔP and P , calculate $\frac{K}{P} = \frac{\Delta K}{\Delta P}$.

Table A3: For *given* K , ΔP and P , calculate $\Delta K = K \frac{\Delta P}{P}$.

Both formulae follow from setting the left-hand side of expression (1) to 0. Tables A2 and A3 will be discussed below.

Discussion

The interplay of capital accumulation and population growth leads, according to the methodology developed in this paper, to a wide range of developing countries where wealth per capita is in fact declining. To judge this result, it is essential to discuss some of the issues with the methodology applied.

The most obvious potential weakness in the method is that it does not proceed, asset by asset, by adding up distinct components of national wealth such as buildings, machinery and equipment, infrastructure, commercial land, natural resource stocks, and so on. This is a fair criticism, but it ignores the evidence that the major part, perhaps 60-70% or more, of value added in GDP comes from factors other than these assets, including human capital, creativity, and social and institutional capital.

A key conclusion from Table 2 is that the finding of negative growth in wealth per capita in the lowest income deciles holds over a wide range of wealth estimates. For decile 1 for example, varying the rate of time preference leads to a 33% decrease in wealth, but only a very marginal change in the percentage decline in wealth per capita. The percentage change in wealth is completely dominated by the population growth rate.

One point to note about potential biases in the methodology is that the reclassification of education, primary health care and R&D expenditures from consumption to genuine saving serve to increase the estimated percentage change in total wealth. These adjustments all have the effect of increasing the numerator, genuine savings, while decreasing the denominator, total wealth, in expression (1), and therefore of increasing the likelihood that changes in wealth per capita will be positive.

The final column of Table A1 calculates the implicit rate of return on assets for the observed per capita income and estimated wealth per capita. As noted earlier, this leads to the not unreasonable value of 6.3% in the United States, and the median value in this table is 7.4%. The extreme values are 12.5% for Botswana and 5.9% for Lesotho. Generally speaking, the assumed

higher discount rate for poor countries tends to reduce estimated wealth and boost the implicit rate of return for these countries. Richer countries with high genuine saving (and therefore low consumption) have similarly elevated rates of return.

Table A2 displays how low the estimated wealth would have to be in order to move countries from negative to zero change in wealth per capita. To give a feeling for what may be unreasonably low wealth estimates, the corresponding implicit rate of return is also shown in this table (countries with negative genuine savings or implicit rates of return at or below the median value are excluded from the table). There are 54 countries with above-median rates of return, 48 with rates of return above 10%, and most much higher than this.

Table A3 highlights countries where the 'savings gap' (the implied rate of genuine saving needed for zero change in wealth per capita, taking the estimated wealth as given, minus the observed rate of genuine saving) is greater than 10%. There are 47 such countries.

Perhaps the most serious challenge to the results of the wealth estimation arises from Figure 5, which scatters change in wealth per capita against the growth rate in per capita GDP.

Figure 5. Change in wealth per capita vs. GDP per capita growth rate.

The lower right quadrant of this figure highlights the fact that there are a considerable number of countries with positive growth rates in per capita GDP (these are the average rates from 1990-97 shown in Table A1), but declining wealth per capita. Are these findings consistent?

To the extent that growth arises from squeezing more productivity from existing assets, the results are compatible. Productive assets like human capital and buildings and machines have

their productivity constrained by bad government policies in many countries. The trend toward liberalization of the economies of developing countries has produced growth, and this liberalization has permitted higher output from existing assets. However, there must be an upward limit on the ability of existing assets to yield greater productivity, which suggests that eventually declines in wealth must produce an impact on output growth per capita.

The other key point to note is that the use of genuine saving in the change in wealth calculation adds an element that is invisible in standard GDP accounts. In particular, GDP as a gross measure counts resource depletion as part of value added. This gives a particularly distorted picture of income in resource-dependent economies where depletion is substantial. So there can be apparent growth in GDP that would not be paralleled in a truer measure of income.

An apparent anomaly in the wealth estimation methodology is that higher levels of consumption translate into higher levels of estimated wealth. It should be recalled, however, that the methodology attempts to estimate a reasonable value for current wealth rather than future wealth. Genuine saving is a better indicator of future wealth. Implicit in the methodology is the fact that observed consumption per capita embodies a substantial amount of information about the size and productivity of the total capital stock. As regards the question of the share of consumption in national income, it is notable that the countries with the highest consumption share (i.e. the lowest gross savings rate) are predominantly the least wealthy countries in this analysis.

This issue of the share of consumption in national income does lead to a puzzling result in Table A1. From this table it can be seen that Finland and France have very similar levels of income per capita, nearly identical rates of population growth, and yet France appears to be richer than Finland by \$40,000 per capita. The reason for this result, of course, is the higher ratio of consumption to income in France (reflected in the table by a significantly lower genuine saving rate). The 'solution' to this conundrum is to note that Finland is accumulating wealth per capita at a rate that is nearly \$1000 per person per year higher than in France – it is building the basis for future wealth and, ultimately, higher levels of consumption derived from this wealth.

The role of technological change has not been discussed in detail in this study, and yet it is clearly germane to any discussion of wealth. Two points are worth noting. First, to the extent that technological change is an endogenous process, then classifying R&D expenditures as investments is a satisfactory treatment of the accounting issues. Second, whether technological change is exogenous or endogenous, its cumulative effect is captured in the level of per capita consumption which it enables – future growth in technology (and therefore consumption) do not enter into the wealth calculation because of the unitary elasticity of the marginal utility of consumption which is assumed.

As Weitzman and Löfgren (1997) show, exogenous technological change can add substantially to Hicksian income. Appendix 1 explores the extent to which this has an impact on wealth and genuine saving estimates. If observed rates of per capita total factor productivity growth in the United States are assumed to be the result of exogenous processes, this Appendix shows that genuine saving in the US would jump from 13.2% to 21.2%, while the change in wealth per capita would increase from 0.1% to 0.6%. While this result is significant for the

United States and, presumably, for other advanced economies, it relies upon technological change being a completely exogenous process. Moreover, technological change in developing countries, as measured by growth in total factor productivity, is a much smaller factor than in the developed world.

Finally, it is worth considering the effects of endogenizing population growth in the underlying model for wealth estimation. This would typically proceed by specifying the population growth rate to be a declining function of wealth per capita. To the extent that the wealth estimates derived in this paper are robust, the preponderance of poor countries on a declining path of wealth per capita would imply increasing population growth rates and the descent into a poverty trap in such a model of endogenous population growth.

Conclusions

The broad conclusion from this analysis is clear from Tables A1 and 2. There is evidence to suggest that, with the notable exception of China, the majority of countries lying below median income per capita are accumulating total wealth – produced assets, infrastructure, natural resources, human capital, social and institutional capital, human health and R&D – at a rate lower than the rate of population growth. While there is ample scope in these countries to achieve higher economic output from existing assets, basically by giving greater scope to markets and developing the institutions that support the operation of markets, this trend in total wealth per capita is ultimately not sustainable.

Table A2 increases the confidence we can have in these results. It is difficult to get an intuitive feel for what constitutes a wealth estimate that is ‘too low’ for a given country. But the implicit rate of return calculation does just that. It suggests that the estimated wealth presented here would have to be very substantially reduced in order to bring 40 or more countries onto a path with non-declining wealth per capita. It is reasonable to conclude that these countries are on an unsustainable path. To these 40 can be added another 10 countries with negative genuine savings.

If the wealth estimates are reasonable and population growth rates are given, then Table A3 suggests that truly heroic increases in savings rates would be required to bring the 47 countries highlighted onto a sustainable path. Chad would have to achieve a higher genuine savings rate than Singapore, for example. Hamilton and Clemens (1999) discuss the policies needed to boost genuine savings, spanning macroeconomic policies, investments in human capital, and policies to increase the efficiency with which the environment is used. But the bottom line in Table A3 is that reducing population growth must play an important role in launching many countries onto a sustainable path. The positive agenda for reducing population growth involves such key elements as increasing female education and reducing infant and child mortality, yielding very substantial social and economic benefits as byproducts.

The change in wealth per capita estimates are highly sensitive to population growth rates, as the US example (Table 1) illustrates. Increasing the population growth rate by 0.2% per year

in the United States (i.e., retaining its historical trend of the past 15 years) reduces the change in wealth per capita by \$1000, and leads to declining wealth per capita.

The wealth estimation methodology presented here could be made considerably less arbitrary if there were (i) widespread data on net health investment, and (ii) studies on rates of time preference across countries, particularly in developing countries. The other controversial element of the methodology, the 25 year period for present value calculations, could be replaced by something like the average years of remaining life employed in *Expanding the Measure of Wealth*. However, most alternative choices of a period for the estimation would tend to yield values greater than 25 years, inflating the wealth estimate and decreasing the estimated accumulation of wealth per capita.

There is further value to the exercise in this paper, since it gives sharp focus to the question of what is actually consumption, and what is investment. These and similar questions should encourage us to continue to refine our national accounting measures, better adapting them to deal with the challenges inherent in measuring development progress.

Table A1. Change in wealth per capita by country, 1997.

	GDP / capita \$	GDP growth rate 1990-97, %	Population growth rate, %	Genuine Saving % of GDP	Estimated wealth / capita, \$	Change in wealth / capita, \$	Change in wealth / capita, %	Implicit rate of return, %
Algeria	1,606	0.8	2.3	33.9	15,500	185	1.2	10.4
Angola	657	-1.2	2.9	8.9	7,400	-153	-2.1	8.9
Argentina	9,110	5.4	1.2	12.7	139,800	-499	-0.4	6.5
Australia	21,234	3.6	1.0	10.5	319,300	-1,115	-0.3	6.7
Austria	25,548	2.0	0.2	17.7	369,900	3,889	1.1	6.9
Azerbaijan	579	-15.1	1.0	-25.8	8,600	-234	-2.7	6.7
Bangladesh	335	4.7	1.8	11.0	4,500	-43	-1.0	7.4
Belarus	2,204	-6.1	-0.1	14.6	27,400	338	1.2	8.0
Belgium	23,800	1.4	0.1	19.7	349,600	4,419	1.3	6.8
Benin	369	4.5	2.8	11.7	5,200	-103	-2.0	7.1
Bolivia	1,027	4.1	2.1	7.5	14,700	-232	-1.6	7.0
Botswana	3,307	4.5	2.2	44.2	26,400	892	3.4	12.5
Brazil	5,012	3.4	1.4	19.5	70,500	-36	-0.1	7.1
Bulgaria	1,213	-3.3	-0.5	12.9	15,900	244	1.5	7.6
Burkina Faso	229	3.3	2.4	14.5	3,000	-37	-1.2	7.6
Burundi	149	-3.6	2.4	-1.3	2,100	-53	-2.5	7.1
Cameroon	654	-0.1	2.6	9.1	8,700	-169	-1.9	7.5
Canada	20,066	2.2	0.9	15.6	292,500	587	0.2	6.9
Central Afr Rep	298	1.2	1.9	11.0	4,100	-48	-1.2	7.3
Chad	224	4.6	2.7	-0.8	3,500	-97	-2.8	6.4
Chile	5,272	8.3	1.3	19.5	69,300	105	0.2	7.6
China	735	11.6	1.0	38.0	6,800	212	3.1	10.8
Colombia	2,391	4.4	1.7	14.0	33,200	-230	-0.7	7.2
Congo, Dem. Rep.	131	-6.0	3.1	9.6	1,800	-42	-2.3	7.3
Congo, Rep.	849	0.7	2.7	15.1	7,700	-79	-1.0	11.0
Costa Rica	2,748	3.8	1.9	34.8	32,700	347	1.1	8.4
Côte d'Ivoire	721	3.0	2.4	23.4	8,500	-40	-0.5	8.5
Czech Republic	5,050	-0.2	-0.1	20.9	60,000	1,097	1.8	8.4
Dominican Rep	1,855	5.1	1.7	20.9	24,800	-42	-0.2	7.5
Ecuador	1,656	3.1	2.0	9.1	21,900	-277	-1.3	7.6
Egypt, Arab Rep.	1,253	4.0	1.9	9.4	17,800	-220	-1.2	7.0
El Salvador	1,900	5.6	1.6	3.7	31,100	-433	-1.4	6.1
Estonia	3,211	-3.8	-0.4	14.8	43,400	630	1.5	7.4
Finland	23,315	1.4	0.3	18.4	318,200	3,299	1.0	7.3
France	23,760	1.3	0.3	15.1	359,600	2,394	0.7	6.6
Gabon	4,471	3.2	2.5	26.6	37,200	260	0.7	12.0
Gambia, The	345	2.2	2.9	0.3	5,000	-145	-2.9	6.9
Germany	25,494	1.4	0.1	16.8	375,100	4,025	1.1	6.8
Ghana	383	4.2	2.7	6.7	5,600	-125	-2.2	6.8
Guatemala	1,690	4.1	2.4	4.9	27,100	-572	-2.1	6.2
Guinea	562	5.0	2.4	2.0	7,000	-154	-2.2	8.0
Guinea-Bissau	234	3.4	2.0	7.3	3,300	-48	-1.5	7.1
Honduras	750	3.3	2.6	23.5	9,200	-64	-0.7	8.2
Hungary	4,503	-0.2	-0.3	29.4	54,600	1,491	2.7	8.2
India	396	6.0	1.6	12.7	4,800	-27	-0.6	8.3
Indonesia	1,073	7.5	1.5	22.1	12,900	42	0.3	8.3
Ireland	20,494	7.0	0.5	31.3	254,300	5,027	2.0	8.1
Israel	16,806	5.8	1.9	5.0	277,500	-4,476	-1.6	6.1
Italy	19,915	1.1	-0.1	16.3	295,800	3,479	1.2	6.7
Jamaica	1,619	0.4	1.0	11.3	20,100	-14	-0.1	8.1
Japan	33,232	1.5	0.2	24.0	423,400	7,087	1.7	7.8
Jordan	1,581	6.3	3.3	4.6	23,800	-707	-3.0	6.6
Kenya	358	2.1	2.5	4.4	4,900	-109	-2.2	7.3
Korea, Rep.	9,622	7.2	0.9	32.1	113,900	2,091	1.8	8.4
Latvia	2,242	-8.5	-0.5	9.6	32,200	369	1.1	7.0

	GDP / capita \$	GDP growth rate 1990-97, %	Population growth rate, %	Genuine Saving % of GDP	Estimated wealth / capita, \$	Change in wealth / capita, \$	Change in wealth / capita, %	Implicit rate of return, %
Lesotho	472	7.8	2.1	-7.2	8,000	-202	-2.5	5.9
Lithuania	2,587	-7.1	0.2	19.1	36,000	433	1.2	7.2
Madagascar	251	0.9	2.7	6.8	3,700	-83	-2.2	6.8
Malawi	245	3.6	2.6	-0.9	3,600	-96	-2.7	6.8
Malaysia	4,545	8.6	2.1	36.3	42,300	749	1.8	10.7
Mali	246	3.3	2.7	13.7	3,300	-56	-1.7	7.5
Mauritania	446	4.2	2.5	-5.0	6,100	-178	-2.9	7.3
Mauritius	3,831	5.0	0.9	22.7	52,100	380	0.7	7.4
Mexico	4,271	2.2	1.7	19.3	54,300	-74	-0.1	7.9
Mongolia	339	-0.6	2.0	7.8	3,900	-50	-1.3	8.7
Morocco	1,227	1.9	1.8	17.5	16,400	-74	-0.4	7.5
Mozambique	166	4.9	1.8	15.7	2,100	-12	-0.6	7.9
Namibia	2,022	3.8	2.3	8.6	29,000	-492	-1.7	7.0
Nepal	221	5.1	2.3	4.5	2,900	-57	-2.0	7.6
Netherlands	23,084	2.4	0.4	23.5	313,600	4,258	1.4	7.4
New Zealand	17,169	3.4	0.8	19.9	250,800	1,432	0.6	6.8
Nicaragua	421	4.1	2.5	8.4	6,100	-116	-1.9	6.9
Niger	189	1.5	3.2	6.0	2,700	-76	-2.8	7.0
Nigeria	338	2.8	2.7	-10.4	4,300	-152	-3.5	7.9
Pakistan	480	4.2	2.4	6.1	6,900	-138	-2.0	7.0
Panama	3,032	4.8	1.6	36.9	32,300	600	1.9	9.4
P. New Guinea	1,031	5.7	2.1	19.2	10,200	-12	-0.1	10.1
Paraguay	2,002	3.1	2.4	18.9	27,200	-285	-1.0	7.4
Peru	2,620	6.2	1.8	21.7	36,300	-82	-0.2	7.2
Philippines	1,117	3.3	2.2	8.4	16,200	-258	-1.6	6.9
Poland	3,510	4.1	0.3	18.4	47,200	495	1.0	7.4
Romania	1,545	-0.3	-0.1	11.5	21,100	198	0.9	7.3
Russian Fed.	3,034	-7.7	0.0	3.0	38,700	86	0.2	7.8
Rwanda	236	-5.7	2.3	-4.4	3,800	-98	-2.6	6.2
Saudi Arabia	6,996	1.7	3.8	-10.7	79,800	-3,770	-4.7	8.8
Senegal	517	2.5	2.6	17.2	6,800	-86	-1.3	7.6
Sierra Leone	173	-4.4	2.1	-9.3	2,800	-74	-2.7	6.2
Singapore	31,036	8.5	1.4	41.7	290,900	8,942	3.1	10.7
Slovak Republic	3,615	0.6	0.3	23.6	41,300	730	1.8	8.8
Slovenia	9,165	1.4	0.1	17.3	122,200	1,487	1.2	7.5
South Africa	3,179	1.5	1.7	13.0	41,200	-280	-0.7	7.7
Spain	13,530	1.6	0.0	17.3	200,400	2,249	1.1	6.8
Sri Lanka	814	5.3	1.2	16.4	11,200	-1	0.0	7.3
Sweden	25,724	0.9	0.2	18.8	370,000	4,051	1.1	7.0
Syrian Arab Rep	1,202	6.3	2.7	0.5	15,600	-415	-2.7	7.7
Tanzania	221	2.7	2.6	9.0	3,100	-61	-2.0	7.1
Thailand	2,540	7.4	1.1	30.7	27,100	481	1.8	9.4
Togo	339	1.9	2.7	11.8	4,500	-81	-1.8	7.5
Trinidad & Tobago	4,507	1.2	1.0	13.4	55,900	48	0.1	8.1
Tunisia	2,055	4.3	1.7	22.5	24,700	32	0.1	8.3
Turkey	2,979	4.1	1.7	19.3	41,700	-121	-0.3	7.1
Uganda	324	7.4	2.5	4.5	4,700	-103	-2.2	6.9
Ukraine	980	-13.1	-0.3	3.7	12,500	77	0.6	7.8
United Kingdom	21,802	2.0	0.2	11.6	353,000	1,952	0.6	6.2
United States	29,271	3.0	0.8	13.2	461,500	322	0.1	6.3
Uruguay	6,115	4.0	0.6	12.4	96,000	141	0.1	6.4
Venezuela	3,841	2.2	2.0	5.6	47,500	-718	-1.5	8.1
Vietnam	324	8.6	1.7	12.4	4,000	-27	-0.7	8.1
Zambia	409	1.0	2.4	6.2	5,700	-114	-2.0	7.2
Zimbabwe	777	1.8	2.1	7.6	10,100	-153	-1.5	7.7

Table A2. Level of wealth / capita consistent with no change in wealth / capita.

	GDP / capita \$	Estimated wealth / capita, \$	Change in wealth / capita, %	Break-even wealth / capita, \$	Break-even rate of return, %
Gambia, The	345	5,000	-2.9	40	862.2
Syrian Arab Rep	1,202	15,600	-2.7	200	600.9
Guinea	562	7,000	-2.2	500	112.4
Jordan	1,581	23,800	-3.0	2,200	71.9
Kenya	358	4,900	-2.2	600	59.7
Nepal	221	2,900	-2.0	400	55.2
Uganda	324	4,700	-2.2	600	54.0
Guatemala	1,690	27,100	-2.1	3,400	49.7
Niger	189	2,700	-2.8	400	47.3
El Salvador	1,900	31,100	-1.4	4,300	44.2
Madagascar	251	3,700	-2.2	600	41.8
Pakistan	480	6,900	-2.0	1,200	40.0
Israel	16,806	277,500	-1.6	43,700	38.5
Ghana	383	5,600	-2.2	1,000	38.3
Zambia	409	5,700	-2.0	1,100	37.2
Venezuela	3,841	47,500	-1.5	11,000	34.9
Angola	657	7,400	-2.1	2,000	32.9
Congo, Dem. Rep.	131	1,800	-2.3	400	32.7
Nicaragua	421	6,100	-1.9	1,400	30.1
Cameroon	654	8,700	-1.9	2,300	28.4
Bolivia	1,027	14,700	-1.6	3,700	27.8
Zimbabwe	777	10,100	-1.5	2,800	27.7
Tanzania	221	3,100	-2.0	800	27.6
Namibia	2,022	29,000	-1.7	7,500	27.0
Mongolia	339	3,900	-1.3	1,300	26.1
Philippines	1,117	16,200	-1.6	4,300	26.0
Guinea-Bissau	234	3,300	-1.5	900	25.9
Benin	369	5,200	-2.0	1,500	24.6
Togo	339	4,500	-1.8	1,500	22.6
Ecuador	1,656	21,900	-1.3	7,700	21.5
Mali	246	3,300	-1.7	1,200	20.5
Egypt, Arab Rep.	1,253	17,800	-1.2	6,200	20.2
Congo, Rep.	849	7,700	-1.0	4,700	18.1
Central Afr Rep	298	4,100	-1.2	1,700	17.5
Burkina Faso	229	3,000	-1.2	1,400	16.3
Bangladesh	335	4,500	-1.0	2,100	16.0
Senegal	517	6,800	-1.3	3,400	15.2
Vietnam	324	4,000	-0.7	2,400	13.5
South Africa	3,179	41,200	-0.7	24,500	13.0
Paraguay	2,002	27,200	-1.0	15,500	12.9
India	396	4,800	-0.6	3,100	12.8
Colombia	2,391	33,200	-0.7	19,700	12.1
Mozambique	166	2,100	-0.6	1,400	11.8
Honduras	750	9,200	-0.7	6,700	11.2
P. New Guinea	1,031	10,200	-0.1	9,600	10.7
Côte d'Ivoire	721	8,500	-0.5	6,900	10.5
Morocco	1,227	16,400	-0.4	12,200	10.1
Australia	21,234	319,300	-0.3	212,800	10.0
Argentina	9,110	139,800	-0.4	97,800	9.3
Turkey	2,979	41,700	-0.3	34,400	8.7
Jamaica	1,619	20,100	-0.1	18,700	8.7
Mexico	4,271	54,300	-0.1	49,900	8.6
Dominican Rep	1,855	24,800	-0.2	22,300	8.3
Peru	2,620	36,300	-0.2	31,700	8.3

Note: Negative genuine saving countries excluded.

Table A3. Genuine saving consistent with no change in wealth /capita.

	Genuine Saving % of GDP	Estimated wealth / capita, \$	Change in wealth / capita, %	Break-even Gen. Saving % of GDP	Saving gap, % of GDP
Saudi Arabia	-10.7	79,800	-4.7	43.2	53.9
Nigeria	-10.4	4,300	-3.5	34.9	45.3
Jordan	4.6	23,800	-3.0	49.4	44.8
Chad	-0.8	3,500	-2.8	42.6	43.3
Sierra Leone	-9.3	2,800	-2.7	33.7	43.0
Lesotho	-7.2	8,000	-2.5	35.7	42.9
Gambia, The	0.3	5,000	-2.9	42.4	42.1
Rwanda	-4.4	3,800	-2.6	37.4	41.8
Azerbaijan	-25.8	8,600	-2.7	14.6	40.3
Mauritania	-5.0	6,100	-2.9	34.8	39.8
Niger	6.0	2,700	-2.8	45.8	39.7
Malawi	-0.9	3,600	-2.7	38.2	39.1
Burundi	-1.3	2,100	-2.5	33.7	35.1
Syrian Arab Rep	0.5	15,600	-2.7	35.0	34.5
Guatemala	4.9	27,100	-2.1	38.7	33.8
Madagascar	6.8	3,700	-2.2	40.1	33.3
Congo, Dem. Rep.	9.6	1,800	-2.3	42.2	32.5
Ghana	6.7	5,600	-2.2	39.1	32.4
Uganda	4.5	4,700	-2.2	36.4	31.9
Kenya	4.4	4,900	-2.2	34.8	30.3
Pakistan	6.1	6,900	-2.0	34.9	28.7
Nicaragua	8.4	6,100	-1.9	36.1	27.7
Benin	11.7	5,200	-2.0	39.4	27.7
Zambia	6.2	5,700	-2.0	33.8	27.6
Guinea	2.0	7,000	-2.2	29.3	27.4
Tanzania	9.0	3,100	-2.0	36.0	27.0
Israel	5.0	277,500	-1.6	31.6	26.6
Cameroon	9.1	8,700	-1.9	35.0	25.9
Nepal	4.5	2,900	-2.0	30.0	25.5
Namibia	8.6	29,000	-1.7	32.9	24.4
Togo	11.8	4,500	-1.8	35.4	23.6
Angola	8.9	7,400	-2.1	32.3	23.4
Mali	13.7	3,300	-1.7	36.7	23.0
Philippines	8.4	16,200	-1.6	31.4	23.0
El Salvador	3.7	31,100	-1.4	26.5	22.8
Bolivia	7.5	14,700	-1.6	30.0	22.5
Guinea-Bissau	7.3	3,300	-1.5	27.8	20.5
Zimbabwe	7.6	10,100	-1.5	27.3	19.6
Venezuela	5.6	47,500	-1.5	24.3	18.7
Egypt, Arab Rep.	9.4	17,800	-1.2	27.0	17.6
Ecuador	9.1	21,900	-1.3	25.8	16.8
Senegal	17.2	6,800	-1.3	34.0	16.8
Burkina Faso	14.5	3,000	-1.2	31.1	16.6
Central Afr Rep	11.0	4,100	-1.2	26.8	15.9
Mongolia	7.8	3,900	-1.3	22.7	14.9
Paraguay	18.9	27,200	-1.0	33.1	14.2
Bangladesh	11.0	4,500	-1.0	23.7	12.7

Appendix 1: Exogenous Technological Change and Resource Depletion

The effects of exogenous technological change on a measure of NNP and its implications for sustainability have been analysed in some detail recently by Weitzman and Löfgren (1997). For an economy with fixed population and labour force (which is therefore factored out of the model below), exogenous technological change is modeled by assuming that total factor productivity grows at some fixed rate γ , so that the national accounting identity for *gross* national product is,

$$GNP \equiv F(K, R, t) = Ae^{\gamma t} K^\alpha R^\beta = C + \dot{K}, \text{ for } \alpha + \beta < 1.$$

Here A represents total factor productivity, K capital, R resources, C consumption, and α and β the elasticities of output with respect to capital and resources respectively. It is assumed that resource extraction from exhaustible stock S is costless. The optimal growth model is therefore,

$$\max V = \int_0^\infty U(C(s))e^{-\delta(s-t)}ds \text{ such that :}$$

$$\dot{K} = F(K, R, t) - C$$

$$\dot{S} = -R.$$

Deriving the conditions for the optimal path, define Q to be the present value of output on this path,

$$Q = \int_0^\infty F(K, R, s)e^{-\int_0^s F_K(\tau)d\tau} ds.$$

Then the analogue to expression (4) can be derived as,

$$U_C(\dot{K} + F_R\dot{S} + \gamma Q) = \dot{V}. \quad \text{A1-1}$$

Integrating this expression will again yield an expression for total wealth on the left-hand side – where total wealth consists of produced capital, natural resources and a notional stock value for exogenous technological growth – which is equal to the integral of U/U_C .

The conclusion is therefore that the present value of consumption on the optimal path can serve as a lower bound for total wealth, even when this wealth is heterogeneous and includes exogenous sources of technological change. Expression A1-1 does suggest, however, a significant change to the measure of genuine saving, owing to the presence of the γQ term.

Using long run figures for growth in per capita GDP in the United States (1.6% from 1965 to 1998), Weitzman and Löfgren's figure of 1.5% per annum total factor productivity growth (or 0.5% per capita), and the consumption rate of interest calculated for the US of 3.4%, the following estimates of change in wealth per capita result:

Adjusted genuine saving, % of GDP	21.2%
Change in wealth per capita, \$	2,655
Change in wealth per capita, %	0.6%

These figures assume that adjusted genuine saving should not include R&D expenditures as investment (since technological change is exogenous) and that population grows at the 0.8% rate assumed in Table 1. Q is measured as the present value of the growing GDP per capita over a 25 year span.

Appendix 2: Cumulative savings vs. direct wealth estimation

Another check of the robustness of the wealth estimation methodology presented in this paper concerns the consistency of the consumption-based estimates with estimates that would be obtained from accumulating genuine savings over time. For an economy where GDP per capita y_t is growing at rate r , and where the savings rate is s , assuming unitary elasticity of the marginal utility of consumption yields the following baseline estimate for total wealth per capita using the consumption-based approach:

$$k_t = \frac{1-s}{\delta} y_t.$$

Denoting the cumulative measure of wealth in the next period as k_{t+1}^* , and the direct consumption-based wealth estimate as k_{t+1} , the following will hold:

$$k_{t+1}^* = k_t + s(1+r)y_t,$$

$$k_{t+1} = (1+r) \frac{1-s}{\delta} y_t.$$

It is clear that these two expressions will not generally be equal – for a given growth rate and rate of time preference, only a specific saving rate will ensure equality. The direct wealth estimation methodology fails this ‘adding up’ test therefore. To get a sense of the magnitude of the deviation, the preceding expressions can be generalized to the n^{th} period as follows:

$$k_{t+n}^* = \frac{1-s}{\delta} y_t + s \cdot y_t \left((1+r) + (1+r)^2 + \dots + (1+r)^n \right)$$

$$k_{t+n} = (1+r)^n \frac{1-s}{\delta} y_t$$

$$\frac{k_{t+n}^*}{k_{t+n}} = \frac{1}{(1+r)^n} + \delta \frac{s}{1-s} \cdot \frac{1+r}{r} \left(1 - \frac{1}{(1+r)^n} \right).$$

Taking aggregate values for saving and per capita growth rates for high income and low income countries from the WDI, and the assumed time preference rates from the body of this paper, the following values for the ratio in expression A2-1 are obtained.

	Growth rate (r)	Saving rate (s)	Time preference (δ)	Period (n)	Ratio of wealth estimates
High income	1.7%	22%	1.5%	10	0.88
Low income	1.3%	17%	3.5%	10	0.95
High income	1.7%	22%	1.5%	20	0.79
Low income	1.3%	17%	3.5%	20	0.90

For low income countries at least, the divergence of the direct wealth estimates from cumulative savings estimates is relatively small, with the direct estimate being the larger of the two.

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