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Comments on Arrow *et al.*, 'Sustainability and the measurement of wealth'

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The Arrow *et al*. paper is a welcome addition to a large literature on the linkage between asset values and social welfare. This literature has its roots in the concern about 'greening' the national accounts, but the paper shows how expanding the asset boundary beyond produced and natural goods could increase our measures of income, saving and wealth enormously. I will comment in turn on the wealth accounts, investment accounts and the treatment of CO_2 emissions, using selected World Bank figures as a basis for comparison.

Comprehensive wealth

Table 1 lays out the year 2000 wealth accounts for the United States, using figures from the paper and figures from *The Changing Wealth of Nations* (World Bank, 2011), expressed in year 2000 US$ and augmented by recent OECD figures on the value of human capital (Liu, 2011).

Implicit in the theorems linking savings and investment to changes in social welfare is an assumption that the accounting is complete – if assets are missing from the accounts, then the change in social welfare and sustainability of an economy may be over- or understated. Expanding the accounting of assets, as Arrow *et al*. do, is therefore inherently important. Looking at the table, most countries which produce asset accounts would be measuring total wealth as US$56–81 thousand per capita; for the handful of countries which include natural assets in the balance sheet, this measure expands to US$76–94 thousand per capita. This falls far short of comprehensive accounting as the other figures in the table reveal.

The discrepancies between Arrow *et al*. and World Bank (2011) for produced and natural capital are presumably linked to different data sources, and different assumptions about depreciation, lifetimes and discount rates. More interesting is the discrepancy in the value of human capital. Liu (2011) uses the Jorgenson–Fraumeni (1989) framework, which relies on projected figures on earnings by educational cohort, while Arrow *et al*. use the Mincer formula and average wages. Since the Jorgenson–Fraumeni methodology employs a much richer set of data to calculate the present value of labor income, it produces what is arguably the more accurate estimate of human capital. This suggests that the Mincer formulation

Table 1. *US wealth in 2000, US$ per capita*

	Arrow et al.	*% wealth*	*World Bank/Liu*	*% wealth*
Produced capital	56,423	0.8	81,423	13.7
Natural capital	20,205	0.3	12,847	2.2
Human capital	229,614	3.4	339,608	57.0
Intangible residual			166,817	28.0
Net foreign assets			−4,999	−0.8
Health	6,356,761	95.4		
Total wealth	6,663,003		595,696	

Source: Arrow *et al*. (2012, table 5); World Bank (2011). Human capital figures for 2005 from Liu (2011) are back-cast to year 2000 using data on per capita income.

should not be used blindly to value human capital, but further digging into the details of the calculations would be required to confirm this conclusion.

The big discrepancy between the two wealth accounts in table 1 is obviously the value of health in Arrow *et al*. Their calculation starts from the US value of a statistical life (VSL) of US$6.3 million, then converts this to a mean value of a life-year and multiplies by the discounted expected years of life to arrive at the total health capital.

While World Bank (2011) values damages from exposure to particulate matter pollution using VSL in its calculation of Adjusted Net Saving, the asset accounts stay closer to the System of National Accounts (SNA) boundary. In particular, as reported in table 1, by assuming constant returns to scale, a reasonably comprehensive measure of total wealth can be derived as the present value of future public and private consumption as measured in the SNA.[1] When the value of other assets, including human capital as calculated in Liu (2011), is subtracted from total wealth, the 'intangible residual' shown in table 1 is the asset equivalent of total factor productivity (TFP) – it implicitly values social capital, institutional quality and other unmeasured assets which support production in the economy.

Returning to the value of health capital in Arrow *et al.*, the interpretation of the VSL merits careful consideration. Both Arrow *et al*. and Nordhaus (2002) assume that it can serve as the value of health or healthfulness, but it arguably includes *everything* that people value in life – consumption of goods, leisure, enjoyment of environmental amenities, relationships with friends and family, and so on, in addition to good health. VSL is, after all, calculated as the willingness to pay to reduce the risk of death. VSL would seem to have much in common with $V(t)$, the value of intergenerational wellbeing defined in expression (1) of Arrow *et al*. $V(t)$ measures the discounted future flow of a very broad measure of utility.

[1] Arrow *et al*. suggest that World Bank (2011) assumes a *positive* constant growth rate of future consumption in calculating total wealth, which is incorrect. It suffices to assume that the growth rate is constant, whether positive, negative or zero.

Table 1a. *Alternative US wealth in 2000, US$ per capita*

	Arrow et al.	*% wealth*
Produced capital	56,423	0.9
Natural capital	20,205	0.3
Human capital	229,614	3.6
Intangible residual	6,050,519	95.2
Total wealth	6,356,761	

Source: Author's calculations.

If VSL is really dollar-valued $V(t)$, then it is natural to think of it as the broadest measure of the per capita wealth of a nation, since it measures the present value of future generalized consumption.[2] An alternative accounting using the figures in Arrow *et al*. could therefore be as shown in table 1a. Here the intangible residual is the set of all assets beyond human, natural and produced capital which yield production services and services which make life worth living – and worth paying to preserve.

Table 1a is obviously rather speculative, but it makes the point that there is merit in thinking hard about what VSL is actually measuring.

Investment

Health capital

Arrow *et al*. value investment in health capital as the mean value of a life-year (based on the VSL) times the discounted increase in life expectancy. This is clearly an outcome rather than an investment *per se* and it is worth considering what investments actually produce this outcome.

One point is clear, that the investments affecting life expectancy are typically in the past and diverse in nature. Childhood vaccination, prenatal care for mothers, higher income, improved knowledge about nutrition, declines in smoking, decreasing shares of dangerous jobs in the economy, enforcement of health and safety regulations in the workplace, reductions in environmental pollution, testing and control of toxic chemicals, and a wide range of other changes in the economy over preceding decades all contribute to increasing life expectancy. It seems challenging to define and measure the specific investments which produce better health outcomes far into the future.

Capital gains on natural resources

Arrow *et al*. note the theoretical contributions of Asheim (1997) and Sefton and Weale (1996) on this topic, and it is worth noting the work on theory

[2] The main difference between VSL and $V(t)$ is that VSL is only measuring the value of life to the current generation. But if mean expected years of life is 35 years and the pure rate of time preference is 1.5 per cent, then generations beyond the current one only have a 3 per cent weight in $V(t)$.

and measurement of both Vincent *et al*. (1997) and Hamilton and Bolt (2004). While the latter two papers focus on exporters of natural resources, Arrow *et al*. correctly note that the same logic of adjusting saving to reflect exogenous price trends also applies to imports.

Arrow *et al*. firmly reject the assumption of an optimal economy at the outset of the paper, so it is surprising to find it appearing in the calculation of capital gains, where resource prices are assumed to rise at the rate of interest. Livernois (2009) reviews a broad literature and finds virtually no empirical evidence for the Hotelling rule or, indeed, statistically significant rises in resource prices. Plausible explanations for this include the role of resource discoveries and technological change. While Livernois (2009: 27) notes the strong rise in resource prices from 2001 to 2008, he also notes that these rates of growth were much too high to be consistent with the Hotelling rule and concludes that '... this, combined with the observation that commodity prices are highly volatile, suggests that it would be unwise to expect that prices will continue to rise unabated'.

Accounting for CO_2 emissions

Arrow *et al*. present the theory and measurement of carbon dioxide emissions in their accounts, but there is no explicit discussion of property rights in their presentation. Of particular interest is the case where countries have the right not to be polluted by their neighbors.

Suppose there are N countries and that the damages that CO_2 emissions from country k inflict upon country j in a specific year are given by d_{kj}. The total emissions of CO_2 by country k in the given year are e_k, while the social cost of carbon is s. Now we can define the damages inflicted and the damages suffered by country k.

The total damage inflicted by country k is D_k,

$$D_k = s \cdot e_k = \sum_{j=1}^{N} d_{kj}, \tag{1}$$

while the total damage suffered by country k is M_k,

$$M_k = \sum_{i=1}^{N} d_{ik}. \tag{2}$$

If we assume the property right that each country has the right not to be polluted by its neighbors, and that compensation is therefore paid for damage inflicted, the deduction from the national savings of country k to account for global CO_2 emissions is given by

$$-M_k - (D_k - d_{kk}) + (M_k - d_{kk}) = -D_k. \tag{3}$$

In the left-hand side of this expression the first term is the total damage that country k suffers from CO_2 emissions, including its own; the second term is the payment country k makes to all other countries for damage inflicted; and the third term is the payment that country k receives from all other countries for the damage they have inflicted on it. The net result is that the deduction from the saving of country k just equals the total social cost of its emissions (expression (1)) – this is the valuation applied in Hamilton and Clemens (1999)[3] and World Bank (2011).

Clearly, if no property rights apply to transboundary pollution, then the deduction from the saving of country k is just the total damage it suffers, M_k. This is the value calculated by Arrow *et al*.

These options for the treatment of CO_2 emissions (or, more generally, any transboundary pollutants) are analogous to the difference between GDP and GNP. In one case you measure all the value added within a country; in the second case you account for the flows of factor payments according to whether they accrue to domestic or foreign owners.

One could argue that assuming the property right behind expression (3) is unrealistic. But it is precisely this property right which is the basis for the entire body of international environmental law. It is enshrined in the UN Framework Convention on Climate Change (UNFCCC), which states that 'States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction . . .'. All countries are signatories to the UNFCCC, with only Andorra and the Holy See opting for observer status.

Conclusions

In the introduction to this commentary I described Arrow *et al*. as a welcome addition to the literature on asset accounting and social welfare. Their attempt to be as comprehensive as possible in their accounting is important, as is the rigor with which they approach the problem. My comments on the paper serve to highlight some of the rich avenues for further research which the paper has opened.

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