Inclusive Wealth as a Metric of Sustainable Development

Stephen Polasky,[1,2,*] Benjamin Bryant,[3] Peter Hawthorne,[2] Justin Johnson,[2] Bonnie Keeler,[2] and Derric Pennington[2,4]

[1]Department of Applied Economics, [2]Natural Capital Project, Institute on the Environment, University of Minnesota, St. Paul, Minnesota 55108; email: polasky@umn.edu, phawthorne@umn.edu, jandrewjohnson@gmail.com, keeler@umn.edu

[3]Natural Capital Project, Stanford University, Stanford, California 94305; email: bpbryant@stanford.edu

[4]World Wildlife Fund, Washington, DC 20037; email; Derric.Pennington@wwfus.org

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*Corresponding author

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Abstract

Inclusive wealth is a measure designed to address whether society is on a sustainable development trajectory. Inclusive wealth is defined as the aggregate value of all capital assets. Increases in inclusive wealth indicate an improved productive base capable of supporting a higher standard of living in the future. To be truly inclusive, measures of inclusive wealth must include the value of all forms of capital that contribute to human well-being: human capital, manufactured capital, natural capital, and social capital. Sustainability concerns have increased attention on the ways of measuring the value of natural capital. We review various attempts to measure natural capital and to incorporate these into inclusive wealth including estimates using national wealth accounts and integrated ecological and economic models used to estimate ecosystem services. Empirically measuring the value of various types of capital in terms of a common metric is hugely challenging, and no current attempt to date can be said to be fully inclusive. Despite the empirical challenges, inclusive wealth provides a clear, coherent, and systematic framework for addressing sustainable development. Combining measures of semi-inclusive wealth that capture forms of capital that can be relatively easily measured in monetary terms with a set of biophysical metrics capturing important aspects of natural capital that are difficult to measure in monetary terms may provide a good set of signals of whether society is proceeding along a sustainable development trajectory.

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1. INTRODUCTION

The expansion of economic activity since the start of the Industrial Revolution has transformed human society and the planet, with both beneficial and detrimental consequences. Average standards of living have shown dramatic benefits with improved health, improved education, and higher per capita income (1). However, increases in economic activity have also put pressure on stocks of natural resources and have caused environmental degradation (2). For some, declining resource stocks, threats to biodiversity, climate change, and local and regional environmental degradation are clear signs that society is on an unsustainable path (3–5). But others point out that living standards continue to improve even with accumulating environmental stresses (6–8).

Is the global social-economic-ecological system on a sustainable development trajectory? Are we currently living well only by depleting natural capital with an inevitable decline in future well-being? Or are we saving and investing in various forms of capital that more than offset any decline in natural resources and environmental quality?

Inclusive wealth is a measure designed to address the sustainable development question. Inclusive wealth, also called comprehensive wealth (9, 10) or genuine wealth (11), is defined as the aggregate value of all capital assets, where the value of a unit of a capital asset is measured by the contribution it makes to increasing current and future human well-being (11). Increases in inclusive wealth indicate an improved productive base capable of supporting a higher standard of living in the future consistent with sustainable development, whereas decreases in inclusive wealth indicate unsustainable development (11–14).

To be truly inclusive, measures of inclusive wealth must incorporate the value of all forms of capital. Ignoring some forms of capital risks sending the wrong signal. For example, not including a declining asset would give a false sense of security about sustainability. We consider five types of capital assets: financial capital, human capital, manufactured capital, natural capital, and social capital. Financial assets are claims on the wealth of society that simultaneously generate a credit and a liability. In the aggregate, financial assets change the distribution of wealth but do not change total wealth. Financial assets are important for describing the wealth of countries, businesses, or households but not for describing global aggregate inclusive wealth. Increases in any of the other four forms of capital, however, do increase global aggregate wealth. Human capital includes the experience, education, and know-how of the population. Manufactured capital includes durable produced items, such as infrastructure, buildings, and machinery. Natural capital includes natural resources (oil, minerals, timber, fish stocks) and ecological processes that contribute to the provision of ecosystem services. Ecosystem services are defined as the goods and services supplied by nature of value to people, such as filtration of nutrients to purify water and pollination for agricultural crops (2). Social capital includes the institutions and relationships among members of society that help make society function. Various authors define categories somewhat differently. For example, Arrow et al. (11) do not include institutions as part of social capital but rather think of institutions as guiding resource allocation. Others consider knowledge capital stored in electronic or print form to be distinct from human capital (education and experience) embodied in individuals (15) or consider human health capital as a separate category (16).

Probably the most well-known definition of sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (17, p. 43). The inclusive wealth approach shares with this definition a concern about current and future generations but differs from it by focusing on well-being rather than needs. In *The Changing Wealth of Nations*, the World Bank describes inclusive wealth as providing "an indication to governments of whether policy, broadly conceived, is producing increases in both current and future well-being . . . " (10, p. 4).

Inclusive wealth has some important advantages as a metric of sustainable development compared to commonly reported measures of economic performance, such as gross domestic product (GDP), which is a measure of the annual value of the production of market goods and services within a country. GDP includes the value of goods and services exchanged in markets but excludes many values of nature that are not partially or fully captured within the market system (e.g., the value of clean air, clean water, climate regulation, aesthetics, and existence of species). Efforts are now underway to expand economic accounts to include the value of nonmarket ecosystem services, but these efforts are still a work in progress (18). GDP also does not indicate whether the value of production can be sustained in the future. For example, the high value of production from a fishery may be the result of overfishing, depleting the fish stock on which future production depends. This last point highlights the importance of measuring the value of capital rather than measuring current income in defining a metric of sustainable development.

Inclusive wealth also has two important advantages relative to most other sustainable development metrics, such as the Human Development Index (19), Ecological Footprint (20), or sustainable development indicators like those produced by Eurostat (21). First, most metrics report current status and past trends but do not forecast the future status. As sustainable development is about prospects for current and future generations, a metric of sustainable development should not only measure the current status but also project how well placed future generations will be to satisfy their needs or well-being. The value of a capital asset, at least in theory, is equal to the present value of rents generated by the asset, so that in principle the value of capital captures expectations about the flow of current and future benefits. Second, inclusive wealth is built on a solid theoretical foundation from economics. Most other sustainable development metrics lack a coherent body of theory on which to support their approach. We review the economic theory used to define inclusive wealth in Section 2 and extensions of the basic theory to cover population growth and technological change in Section 3.

The major drawback of inclusive wealth relative to other sustainable development metrics is that inclusive wealth is quite difficult to measure. Measuring both the amount of different forms of capital as well as the value of a unit of capital is hugely challenging. We discuss several attempts to measure inclusive wealth, and the challenges of doing so, in Section 4. Economic measures of the value of capital assets have traditionally focused on manufactured capital, and estimates of the value of manufactured capital extend back many decades (22). Since the 1960s, efforts have been made to define and measure the value of human capital, particularly the returns to education and experience (23, 24). Efforts to value natural capital are ongoing, although they are currently better at tracking marketed commodities like oil and minerals than nonmarketed ecosystem services (9–11, 16, 18, 25–28). Social capital is perhaps the most difficult form of capital to define and measure as it involves intangibles, such as trust and the degree to which institutions in society are functioning in a proper manner (29).

As we discuss in Section 4, no current measure of inclusive wealth is in fact fully inclusive. At present, there is no empirical estimate that could be said to come close to the ideal of measuring inclusive wealth or how inclusive wealth is changing through time. Without such evidence, the inclusive wealth approach does not provide definitive guidance on whether sustainable development is being achieved. Given these measurement challenges, some have proposed alternatives to inclusive wealth. Stiglitz et al. (30) argue that attempting to come up with a single metric for sustainability, similar to what GDP is for measuring current income, is too ambitious. Instead, they recommend measuring the monetary value of capital assets where it can reasonably be done and augmenting these wealth accounts with a set of biophysical metrics that capture important aspects of natural capital that are difficult or impossible to measure in monetary terms at present. A similar argument could be made for the difficult to value aspects of social capital. In Sections 5 and 6, we address several of critiques of inclusive wealth, including these measurement challenges, as well as issues about the substitutability of capital and whether prices adequately represent contributions to well-being, equity, and uncertainty. We end with concluding thoughts on the contributions of inclusive wealth to the analysis of sustainable development.

2. THE FOUNDATIONS OF INCLUSIVE WEALTH: ECONOMIC GROWTH THEORY

The inclusive wealth approach builds from macroeconomic theory and its study of the evolution of the economy over time, commonly referred to as economic growth theory (descriptions of economic growth theory can be found in virtually all macroeconomics textbooks, e.g., 31, 32). Economic growth theory describes how the aggregate output of an economy changes through time as a function of changes in available inputs. Although it is called economic growth theory, it can in principle describe growing, static, or shrinking economies.

In the simplest economic growth model, capital (K) and labor (L) are combined in an aggregate production function, $F(.)$, to determine the aggregate level of output of the economy (Y): $Y = F(K, L)$ (33, 34). Growth of either capital or labor leads to growth of output. Increasing population without increasing capital stock tends to increase total output through an increase in labor but decrease output per capita, leading to a decline in the standard of living. Conversely, an increase in capital with constant population growth tends to increase both total and per capita output.

This simple formulation leaves out other inputs, such as natural resources and education, which contribute to production. The exclusion of natural capital from economic growth theory has been criticized by some economists and environmental scientists (e.g., 35); however, the aggregate production function can be expanded to include multiple types of capital and other nonlabor inputs. For example, aggregate output could be a function of human capital (H), manufactured capital (M), natural capital (N), and social capital (S), along with labor, and other inputs (X): $Y = F(H, M, N, S, L, X)$. This expansion highlights the fact that aggregate output depends on many factors and that declines in environmental quality or natural resource stocks can negatively impact aggregate output and per capita income.

The basic decision in the economic growth model is how much output to use for consumption, which generates current benefits, and how much output to save and invest in various forms of capital to provide for future consumption (**Figure 1*a***). At any time, t, output can be either consumed (C_t) or saved (S_t): $Y_t = C_t + S_t$. Savings ($S_t = Y_t - C_t$) are assumed to be invested to generate additional capital, which could be any of the above types. In the case with a single capital stock, the change in the capital stock through time (dK_t/dt) is the difference between investment and depreciation (Equation 1):

$$\begin{aligned} dK_t/dt &= S_t - \beta K_t \\ &= Y_t - C_t - \beta K_t, \end{aligned} \tag{1.}$$

where β is the depreciation rate on existing capital (**Figure 1*b***).

Deciding how much output should be consumed versus saved involves evaluating the trade-offs between the benefits of immediate consumption versus the benefits of future consumption. Economists use a utility function, U_i (.), to represent an individual's subjective well-being (utility), which depends on consumption: $U_i(C_{it})$, where C_{it} is the consumption by individual i at time t (**Figure 1*c***). Consistent with the inclusive wealth approach, we use a broad definition of consumption and well-being. Under this definition, consumption can be interpreted to include anything that a person cares about, and well-being may be a function of the aesthetic beauty of the person's surroundings, the existence of biodiversity, as well as the person's consumption of food, clothing, and other material goods. We view using a broad definition of both capital and well-being as essential in the inclusive wealth approach, but this makes it much harder to gather data and make an empirical determination of whether sustainable development is being achieved. We return to this point in Section 4.

Although well-being is defined for an individual, assessing sustainability requires aggregating across individuals to get to a whole system metric. The aggregate level of well-being, or social welfare, $U(C_t)$, could be derived by adding up the well-being of all the individuals in society or by using some more complicated relationship, such as trying to account for inequality by giving greater weight to the well-being of disadvantaged individuals (see Section 5). There is no generally agreed upon best method for aggregation.

The final building block for assessing inclusive wealth involves comparing well-being that occurs in different periods of time, which brings in the issue of discounting (discussed further in Section 5). The present may be valued more highly than the future simply because it occurs now (impatience), which economists model with a parameter called the pure rate of time preference, δ. For someone who values the present more than the future, $\delta > 0$. For someone who equally values the present and the future, $\delta = 0$.

The present value of the flow of well-being, which is determined by consumption through time, which in turn depends on supply of capital assets through time, is given by Equation 2:

$$V(C_t|K_0) = \int_0^T U(C_t)\, e^{-\delta t} dt, \tag{2.}$$

with

$$\frac{dK_t}{dt} = F(K_t, L_t) - C_t - \beta K_t;\ K_0 \text{ given.} \tag{3.}$$

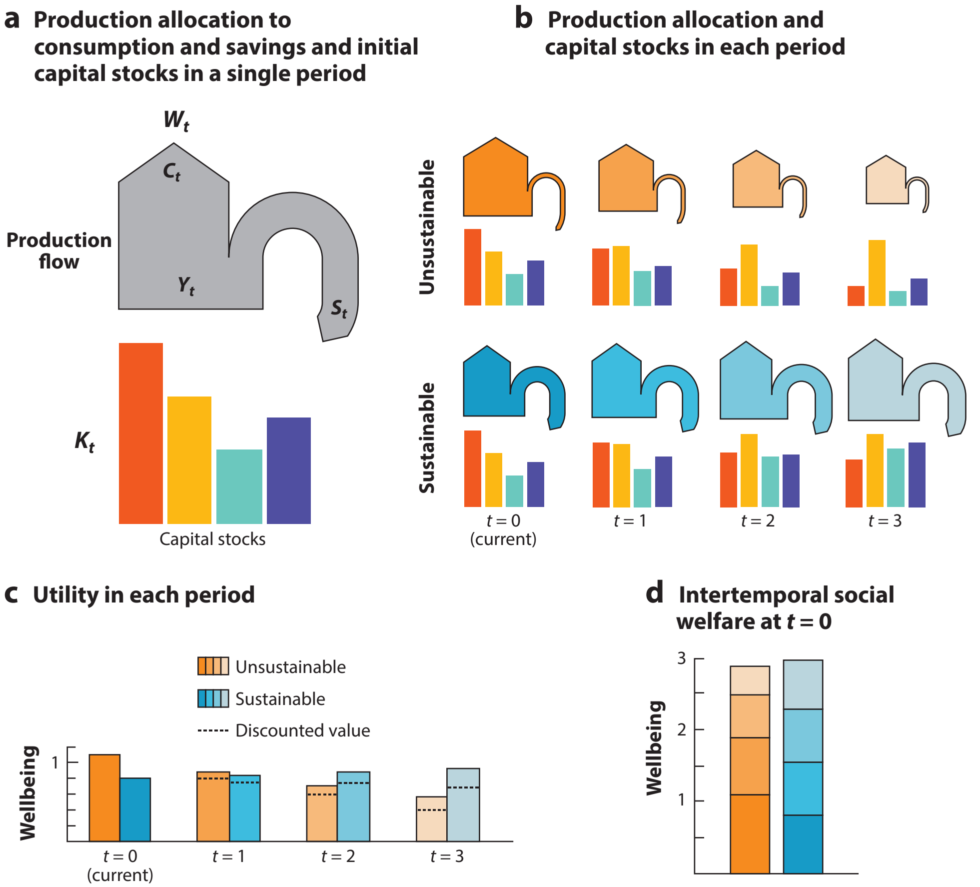

Figure 1

(a) In each time-period, the key decision is how the output, Y_t, produced from a set of capital stocks, K_t, is partitioned between consumption, C_t, and savings, S_t. The proportion of Y_t that is consumed yields well-being, W_t, for those doing the consuming, and the proportion that is saved increases the supply of the various stocks bequeathed to the next time period, increasing maximum potential production in the future. (b) Different decisions about this allocation can lead to sustainable and unsustainable trajectories given identical starting conditions. Along an unsustainble path (*top row*), savings are too small to replace declines in capital from direct consumption or depreciation, so that the productive base and social welfare contract over time. On a sustainable path (*bottom row*), greater savings means that while some forms of capital may decline, increases in others are sufficient to maintain or increase overall output. (c) Measured in terms of the well-being provided by each of these paths, the unsustainable path initially provides greater well-being, but as production declines, even maintaining a high consumption fraction cannot maintain well-being. Choosing between these two paths based only on comparing the well-being provided by each in the current period would lead to choosing the unsustainable path and to facing declining well-being in the future. (d) A decision based on inclusive wealth instead compares changes in intertemporal social welfare along each path. Because the unsustainable path has decreasing inclusive wealth ($dV/dt < 0$), it would be rejected by the sustainability criterion, and the sustainable path ($dV/dt > 0$) would be approved.

Equation 2 represents the present value of the flow of present and future well-being with T being the end point of the period under consideration (T can be infinite). The representative individual chooses consumption in each period C_t and hence savings as well because $S_t = Y_t - C_t$, which determines the capital stock and aggregate output. Equation 3 represents the evolution of the capital stock through time.

Achieving sustainable development requires that intertemporal well-being, $V(C_t|K_t)$, is not declining through time (Equation 4) (11):

$$dV(C_t|K_t)/dt \geq 0. \quad 4.$$

This expression is equivalent to saying that future prospects are always nondeclining. Note that this expression does not guarantee that well-being from one period to the next is always nondeclining, but it does guarantee that intertemporal well-being, the present value of the future flow of well-being, is nondeclining (11). Although the details that go into the definition of nondeclining well-being are complex, the above criterion for determining whether society is achieving sustainable development is exceedingly simple.

To achieve nondeclining well-being, there must be sufficient investment to provide adequate future capital and future income. For constant population, achieving nondeclining well-being requires nondeclining inclusive wealth, i.e., the aggregate value summed across all forms of the capital stock must be nondeclining. We expand the expression for capital to clearly show the importance of various forms of capital in determining nondeclining inclusive wealth: $K_t = (K_{1t}, K_{2t}, \ldots, K_{Jt})$, where K_{jt} is the j^{th} form of capital at time $t, j = 1, 2, \ldots, J$. Taking the derivative of the expression $V(C_t|K_t)$ with respect to time, we have Equation 5:

$$\frac{dV(C_t|K_t)V(K_t)}{dt} = \frac{dV(C_t|K_{1t}, K_{2t}, \ldots, K_{Jt})}{dt} = \sum_{j=1}^{J} \frac{dV(C_t|K_{1t}, K_{2t}, \ldots, K_{Jt})}{dK_{jt}} \frac{dK_{jt}}{dt}. \quad 5.$$

The first term in the summation on the right hand side of this equation, $\frac{dV(C_t|K_{1t},K_{2t},\ldots,K_{Jt})}{dK_{jt}}$, shows how a unit of capital of type j contributes to present and future well-being. Let the accounting price of capital asset j at time t, $P_j(K_t)$, be equal to its contribution to present and future well-being: $P_j(K_t) = \frac{dV(C_t|K_{1t},K_{2t},\ldots,K_{Jt})}{dK_{jt}}$. The second term in the summation, $\frac{dK_{jt}}{dt}$, shows how each type of capital asset j changes with time, i.e., the net investment in capital asset j, I_{jt}. Using these definitions, we find that nondeclining well-being is equivalent to nondeclining inclusive wealth in Equation 6:

$$\frac{dV(C_t|K_t)}{dt} \geq 0 \rightarrow \sum_{j=1}^{J} P_j(K_{jt}) I_{jt} \geq 0. \quad 6.$$

Nondeclining inclusive wealth is also equivalent to having nonnegative inclusive investment. This expression defines what we need to know to show whether society is on a sustainable development trajectory. We need to find the accounting prices and net investment levels for all capital assets. Aggregating changes in the value of various capital assets across all forms of capital determines whether inclusive wealth is increasing, constant, or decreasing. As long as inclusive wealth is nondeclining, the current generation is bequeathing to future generations a greater capability to achieve well-being through time. As we discuss in Section 4, nondeclining inclusive wealth is easier to state in principle than it is to determine empirically.

In a closely related line of research, Hartwick (36, 37) found conditions for achieving sustainable development in an economy with exhaustible resources, such as oil or minerals. Maintaining nondeclining inclusive wealth while depleting an exhaustible resource requires that other assets are increased. The Hartwick Rule (36) finds that investing resource rents into other forms of capital is sufficient to achieving a sustainable outcome.

3. ACCOUNTING FOR POPULATION GROWTH AND TECHNOLOGICAL CHANGE

The previous section described the principles of the inclusive wealth framework in its basic form. Two key simplifications were constant population and an unchanging production function. However, long-term changes in both have large impacts on whether a consumption path provides nondeclining levels of well-being. In this section, we discuss how population growth and technological change can be incorporated into estimates of inclusive wealth.

3.1. Population Growth

Human population is estimated to grow to more than 10 billion people by 2100 (38). Population growth raises an issue about the correct measure to use to judge whether sustainable development is being achieved: Is it growth in inclusive wealth or growth in per capita inclusive wealth? Various authors have argued that it is more appropriate to use a measure of per capita wealth as this corresponds to the experience of the representative (average) person (14, 39). Maintaining nondeclining per capita inclusive wealth requires increasing investment sufficiently so that growth in the value of capital assets exceeds population growth. If the population growth rate at time t is given by Pop_t, increasing per capita inclusive wealth requires $\frac{dV(C_t|K_t)}{dt} - Pop_t \geq 0$. Higher population growth therefore requires a greater investment in the productive base to maintain per capita well-being.

3.2. Technological Change

In contrast to the pressure of population growth, technological change that increases productivity (more output for the same inputs) makes it easier to satisfy sustainable development. Historically, GDP has increased at a faster rate than capital and labor inputs, and this difference (termed the Solow residual) is accounted for by an increase in total factor productivity (TFP) (40). TFP growth reflects improvements in technology and institutions that increase output given constant capital and labor inputs (41, 42). If we were able to correctly measure all capital assets including technology, then it would not be necessary to include a separate TFP term. The necessity of inclusion of TFP indicates that in empirical measurement not all forms of capital are accurately measured, a point we discuss further in Section 4.

Increasing productivity lessens future resource pressure by allowing consumption to increase without corresponding increases in capital stock. To include this effect in the inclusive wealth formulation, we represent changing TFP with a productivity multiplier A_t and define output at time t to be $Y_t = A_t F(K_t, \ldots)$ (27). Arrow et al. (27) utilize an approximation to evaluate how inclusive wealth changes with time that includes TFP. They claim that when the production function $F(K_t)$ has constant returns to scale the economy exhibits steady-state growth and the savings rate is small, then the change in inclusive wealth with TFP growth can be approximated by Equation 7:

$$\begin{aligned}\frac{dV(C_t|A_t, K_t)}{dt} &= \left(\frac{dV\ (C_t|A_t, K_t)}{dA_t}\right)\left(\frac{dA_t}{dt}\right) + \sum_{j=1}^{J} \frac{dV\ (C_t|A_t, K_{1t}, K_{2t}, \ldots, K_{Jt})}{dK_{jt}} \frac{dK_{jt}}{dt}, \\ &= \gamma + \sum_{j=1}^{J} P_j(K_{jt}) I_{jt}\end{aligned} \qquad 7.$$

with the first term, γ, capturing the value of changing TFP over time. In practice, the TFP growth rate has been assumed to be equal to a constant. The effect of TFP growth is to reduce the requirement for investment in the productive base. When γ is positive, the second term can be smaller while still meeting the sustainable development criterion $dV/dt \geq 0$.

3.3. Including Both Population Growth and Technological Change

Taken together, including dynamic terms for population and productivity leads to the updated sustainability criterion (Equation 8):

$$\sum_{j=1}^{J} P_j(K_{jt})I_{jt} - Pop_t + \gamma \geq 0. \tag{8}$$

4. EMPIRICAL MEASURES OF NATURAL CAPITAL AND INCLUSIVE WEALTH

As shown in Sections 2 and 3, the theory of inclusive wealth defines a simple rule for determining whether sustainable development is being achieved. Sustainable development occurs when per capita inclusive wealth is maintained or increased. Evaluating sustainability via inclusive wealth, however, requires an assessment of the changes in value of all types of capital. But assessing the value of all types of capital is a huge challenge. There are many difficulties in measuring human, manufactured, and social capital, and a review could be devoted to the empirical measurement challenges for each. Here, we focus on attempts to measure the value of natural capital along with attempts to integrate this into assessments of inclusive wealth. We review two types of approaches: (*a*) macroeconomic measures using aggregate data and (*b*) measures derived from integrated ecological and economic modeling. At present, neither approach is sufficiently developed to provide an accurate empirical assessment of changes in inclusive wealth, but each is still informative as they provide a degree of evidence on the status and trends of the values of natural capital and inclusive wealth.

4.1. Measures of Inclusive Wealth Derived from National Income and Wealth Statistics

In an early precursor to the inclusive wealth literature dating from the 1970s, Nordhaus & Tobin (43) constructed a measure of economic welfare. Nordhaus & Tobin started with the basic national economic accounting data used to calculate gross national product, but adjusted this to account for depreciation of capital stocks to derive net national product (NNP). They further adjusted NNP to account for durable goods, population growth, the value of leisure time, and other nonmarket goods, plus several other adjustments to arrive at what they termed the actual measure of economic welfare (MEW). They found that

> per capita MEW has been growing more slowly than per capita NNP (1.1 per cent for MEW as against 1.7 per cent for NNP, at annual rates over the period 1929–65). Yet MEW has been growing. The progress indicated by conventional national accounts is not just a myth that evaporates when a welfare-oriented measure is substituted. (43, p. 13)

The Nordhaus & Tobin (43) analysis showed how to use and adjust aggregate economic statistics to measure trends in well-being through time and provided a very early analysis that is quite similar in most respects to recent analyses of inclusive wealth.

Repetto et al. (44) found that accounting for depreciation of natural capital through resource depletion or environmental degradation resulted in lower rates of growth than conventionally measured GDP growth. In Indonesia over the period 1971 to 1984, they found a far slower increase in income when accounting for natural resource depletion as compared to the GDP growth rate of 7.1% per year over this period.

In the 1990s, Pearce & Atkinson (45) evaluated whether savings was larger than the sum of depreciation of manufactured and natural capital to see whether countries were on a sustainable development trajectory. They applied their approach to a set of 18 countries. They found eight countries with positive net savings (Costa Rica, Czechoslovakia, Germany, Hungary, Japan, the Netherlands, Poland, and the United States), two countries with nearly zero net savings (Mexico and the Philippines), and eight countries with negative net savings, indicating they were not on a sustainable development trajectory (Burkina Faso, Ethiopia, Indonesia, Madagascar, Malawi, Mali, Nigeria, and Papua New Guinea).

More recent empirical work has built on the theoretical foundations discussed in Sections 2 and 3 (11, 16, 27, 28, 46). Starting in 2012, the United Nations Environment Programme and the United Nations University International Human Development Programme began publishing periodic Inclusive Wealth Reports (16, 28), which built on the work of Arrow et al. (11, 27). There has also been a series of publications by a team of economists at the World Bank (9, 10, 12). Each of these groups of researchers uses national-level data to evaluate current totals and rates of change in inclusive wealth of various nations. *The Changing Wealth of Nations*, the most recent report by the World Bank (10), includes data on 153 countries with changes in inclusive wealth from 1995 to 2005 for many of these countries. The *Inclusive Wealth Report 2014* (28) estimates the change in inclusive wealth for 140 countries between 1990 and 2010. However, the methods used by the World Bank group differ in several respects from that of Arrow et al. (11, 27) and the Inclusive Wealth Reports (16, 28). Most importantly, the World Bank team assumed a constant growth rate of consumption as a way to overcome missing data about intangible capital (10). But assuming a constant consumption growth rate assumes away the problem of unsustainable growth, making this approach less suitable as a way to measure sustainable development (27).

We begin by summarizing the paper by Arrow et al. (27) because it provides a clear explanation of its empirical methods and results using the approach described in Sections 2 and 3. Arrow et al. (27) reported changes in inclusive wealth for five countries: the United States, China, Brazil, India, and Venezuela, over a five-year period from 1995 to 2000.

They began by measuring changes in human capital, manufactured capital, and natural capital. In the category of natural capital, Arrow et al. (27) included measures of the value of stocks of oil and natural gas, minerals (bauxite, copper, iron, gold, lead, nickel, phosphate, zinc), timber, and forest benefits (a measure of the contribution of forests to recreation, erosion control, water filtration, and habitat services). The measure of forest benefits is fairly crude. It assumes a single value per hectare for forests in developed countries and a different value per hectare for forests in developing countries based on work by the World Bank (9). Arrow et al. (27) also included a measure for damages from climate change for each country by first calculating total global damages, found by multiplying global CO_2 emissions by an estimate of the social cost of carbon (47), and then they multiplied this figure by the fraction of total damages suffered by a particular country (48). Other than CO_2 emissions and forest benefits, all measures included in natural capital were values for market commodities, and all other nonmarket values were excluded.

Arrow et al. (27) found declining values of natural capital for the period 1995–2000 for four of the five countries; the United States was the exception. They combined changes in human, manufactured, and natural capital to come up with an estimate of the change in inclusive wealth

Table 1 Per capita growth rates in inclusive wealth with adjustments for population and technological progress for five countries between 1995 and 2000 [Arrow et al., table 3 (27)]

1. Country	2. Inclusive wealth growth rate	3. Population growth rate	4. Per capita inclusive growth rate accounting for population (column 2 minus column 3)	5. TFP growth[a]	6. Per capita inclusive growth rate accounting for TFP growth (column 4 plus column 5)	7. Per capita GDP growth rate
United States	1.39	1.17	0.22	1.48	1.70	2.93
China	3.86	0.94	2.92	2.71	5.63	7.60
Brazil	1.49	1.50	−0.01	0.15	0.14	0.50
India	2.60	1.74	0.86	1.84	2.70	3.99
Venezuela	1.15	1.98	−0.79	−2.12	−2.94	−1.20

[a]Abbreviations: GDP, gross domestic product; TFP, total factor productivity.

for each of the five countries (which Arrow et al. refer to as the comprehensive wealth growth rate; see column 2 of **Table 1**). The population growth rate (column 3) was subtracted from the inclusive wealth growth rate to get per capita inclusive wealth growth rate (column 4). The increase in productivity over time as measured by TFP growth rate (column 5) was then added to the per capita growth rate in inclusive wealth to get the per capita inclusive wealth growth rate accounting for TFP growth (column 6), which is their preferred measure of the change in inclusive wealth.

Several patterns stand out. First, the per capita inclusive wealth growth rate accounting for TFP growth was positive for four out of five countries; the exception was Venezuela. China had the most rapid increase owing to a rapid increase in inclusive wealth, low population growth, and high TFP growth. The increase in inclusive wealth in China came from a large increase in human and manufactured capital, which more than offset a decline in natural capital. Second, high population growth significantly reduced growth in per capita inclusive wealth (column 4) relative to growth in inclusive wealth (column 2), a result also found elsewhere (e.g., 9, 10, 16, 28, 49). Brazil and Venezuela had positive inclusive wealth growth rates but negative per capita inclusive growth rates. The *Inclusive Wealth Report 2012* (16) found that approximately 25% of countries switch from sustainable to unsustainable when using per capita inclusive wealth rather than inclusive wealth not adjusted for population growth. Third, the per capita growth rate of inclusive wealth adjusted for productivity growth (column 6) was lower than the per capita GDP growth (column 7) in all countries. This result mirrors the pattern found in other work (9, 10, 16, 28, 43, 44). GDP growth rates consistently overstate the true measure of change in well-being. Fourth, as measured by Arrow et al. (27), natural capital makes up a small fraction of inclusive wealth. This result was especially true in developed countries like the United States, where human capital dominates other forms of capital. This mirrors results in other studies that attribute wealth primarily to human capital (9, 10, 16, 28). However, whether this is an accurate reflection of the true relative value of natural capital vis-à-vis human and manufactured capital is less clear. Without better measures of natural capital that include nonmarket values and a better assessment of how changes in natural capital might affect future well-being, it is impossible to say whether natural capital values are low simply because of what is measured or because they have lower value in reality.

The most up-to-date and comprehensive report on the inclusive wealth of nations comes from the *Inclusive Wealth Report 2014* (28). The *Inclusive Wealth Report 2014* uses the same methodology as Arrow et al. (27) but includes coal deposits, classifies managed forests as produced capital rather than natural capital, and updates the values of the regulating and provision services provided by

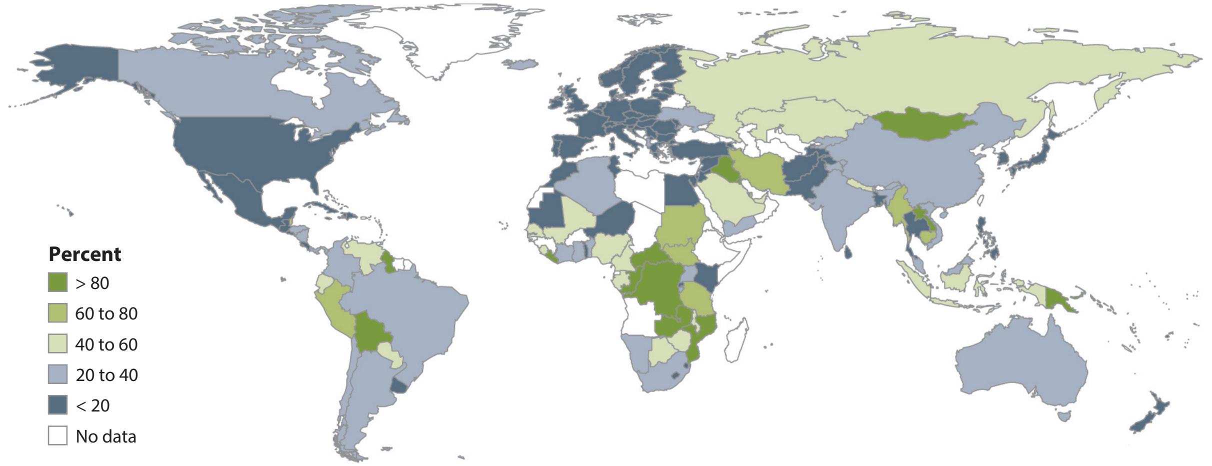

Figure 2

The percentage of inclusive wealth made up by natural capital [e.g., dark green (>80) means that more than 80% of the inclusive wealth of a country is accounted for by natural capital] for 140 countries from the *Inclusive Wealth Report 2014* (28), figure 7a, p. 29.

forests using benefits transfer values derived from Van der Ploeg & De Groot (50). The *Inclusive Wealth Report 2014* (28) estimated that human capital made up 54% of total wealth, followed by natural capital at 28%, and produced (manufactured) capital at 18%. The share of wealth owing to natural capital by country is shown in **Figure 2** (28). Consistent with other studies (9, 10, 27), the share of natural capital is highest in the poorest countries and generally declines with development (see **Figure 2**). The *Inclusive Wealth Report 2014* (28) also found a general trend toward declining natural capital both in absolute and percentage terms. Only 13 countries experienced an increase in natural capital from 1990 to 2010 (28). In contrast, human capital increased in virtually all countries over this time period. The *Inclusive Wealth Report 2014* (28) found increases in inclusive wealth per capita in 85 out of 140 countries (60%) and that growth in per capita inclusive wealth was lower than growth in inclusive wealth not adjusting for population, highlighting the negative impact of population growth. Finally, this report also found that per capita inclusive wealth was lower than GDP growth or increases in the Human Development Index (28).

The national-level inclusive wealth studies have made great progress in showing how measures of change in the value of natural capital based on national data can be used to more accurately account for changes in inclusive wealth over time. Most of these studies show that including changes in the value of natural capital tends to lower the estimated inclusive wealth growth rates, indicating that conventional measures tend to overestimate sustainability. A major shortcoming of this literature is that it is constrained, by and large, to using data from economic accounts that only include marketed goods and services and exclude nonmarket values. Although the principle measures of inclusive wealth can use shadow prices for capital assets without conventional market prices, in practice nonmarket values are not included, and much of what should be included in the value of natural capital is ignored. For example, there are no values estimated for environmental quality that reflect such things as changes in local and regional air quality, water quality, or habitat for biodiversity. The inclusive wealth measures also do not include fisheries or values related to provision of freshwater. Social capital accounts are also largely missing. Therefore, empirical measures of inclusive wealth to date have not really been inclusive and therefore may still overestimate the degree to which society is achieving sustainable development.

4.2. Integrated Ecological and Economic Measures of the Value of Ecosystem Services and Natural Capital

National-level capital asset and wealth statistics facilitate evaluation of sustainable development at the country scale. However, use of national-level income and wealth statistics makes it challenging to incorporate nonmarketed values, thereby leaving out many important ecosystem services and underestimating the value of natural capital. The Millennium Ecosystem Assessment (2) raised awareness of the ongoing global degradation of ecosystem services and highlighted the need to incorporate their value into decision making. A number of studies have since developed and applied integrated ecological and economic methods to quantify the values of various natural capital assets. Some assessments assume static and constant values for different ecosystem types (e.g., grasslands, wetlands) using values for each ecosystem type (51, 52). Other assessments incorporate heterogeneity in both supply and demand for ecosystem services by applying spatially explicit biophysical models measuring change in ecological processes (production, flow) to socioeconomic models estimating the resultant change in the value of both market and nonmarket benefits (53, 54). These models can be applied to evaluate changes in the value of ecosystem services associated with alternative scenarios and can show the present value of the net benefits of a given policy decision. An increase in the present value of net benefits is equivalent to an increase in inclusive wealth, at least to the extent that the net benefit calculations capture all relevant benefits and costs.

There is a growing suite of models designed to assess the value of natural capital assets and the ecosystem goods and services they provide (26, 55, 56). Most of these models rely on ecological production functions that relate a given change in ecosystem conditions to changes in the flow of goods or services. Models for some services are relatively simple relationships between changes in land use or land management and the provision and value of ecosystem services. For example, marginal changes in carbon sequestration can be modeled as changes in the stock of carbon with different types of land cover and valued using a social cost of carbon approach. Services with high temporal or spatial heterogeneity in terms of provision and beneficiaries require more sophisticated approaches and often come with greater data requirements. For example, the values of water-related ecosystem services depend both on the location of where changes in land use and management practices affect pollutant loads and on the locations and characteristics of people affected by those changes (57, 58). The value of clean water can be estimated using water quality models that link changes in land use or management to pollutant loads and transport, and then to consequent changes in ecosystem services sensitive to water quality, such as the net present value of fish or shellfish production (59). Recent work by Fenichel & Abbott (60) presents theoretical and numerical techniques to approximate the value of natural capital, accounting for changes in the value and physical quantity of the capital over time.

This spatially explicit approach of modeling ecosystem production, flows, use, and values has been applied at varying scales and for a variety of decision contexts. At the national scale, Bateman et al. (61) and Lawler et al. (62) assessed the potential impacts of land-use change on a suite of ecosystem services for the United Kingdom and the United States, respectively. The ecosystem services considered included agriculture production, carbon sequestration, recreation, urban green-space amenities, and habitat for species. Both studies compared conventional land-use decision making, emphasizing market values focused on agriculture and urban development with alternative policy scenarios that had incentives to increase natural habitat and improve ecosystem service provision.

Similar assessments have also been conducted at local to regional scales. For example, Polasky et al. (63) used spatial ecosystem services models and a combination of market and nonmarket valuation techniques to estimate net returns under alternative development scenarios for the state of Minnesota. They found that scenarios generating the greatest private returns to landowners were associated with the lowest net social benefits. Incorporating values for nonmarket goods and services, such as clean water and carbon sequestration, changed the ranking of land-use scenarios, providing a means to evaluate the sustainability of alternative development trajectories for the state. Similar assessments of natural capital assets and associated ecosystem services have been used to evaluate alternative development projects (64), the return on investment in conservation policies (65, 66), and future land-use and land management scenarios (53, 67).

Advancements have also been made in understanding the relationships between different types of capital stocks. A recent study of Costa Rica's protected area system found that investments in natural capital also increased the value of human capital stocks in neighboring communities, mostly as a result of increased economic opportunities from ecotourism (68).

Despite significant advancements in biophysical and economic modeling approaches, key challenges remain in making integrated ecologic-economic models useful in the context of inclusive wealth and sustainable development (69, 70). Integrated models need to include system dynamics so that they are capable of predicting not only the current provision of ecosystem services but also future provision. Values of natural capital are sensitive to future conditions that are uncertain. Nonlinear dynamics can result in potentially dramatic and unpredictable changes in systems with large impacts on the value of capital assets (71). A further challenge is that most assessments include a limited suite of ecosystem processes and services. To date, detailed studies that integrate ecological and economic modeling and that are capable of analysis of policy change and dynamics (e.g., 61, 62) are limited to specific services and locations and do not as yet have complete coverage of all values.

5. CRITIQUES OF INCLUSIVE WEALTH

Inclusive wealth is meant to provide information about whether society is on a sustainable development path by assessing whether the total value of capital assets is not declining through time. Some researchers, particularly among noneconomists, are skeptical that measuring the value of capital assets can tell society what it needs to know about sustainable development. In addition to the measurement problems discussed above, there are several other challenges to using and interpreting measures of inclusive wealth. Here, we review four important types of challenges: (*a*) the degree of substitutability among types of capital (strong versus weak sustainability), (*b*) whether prices of capital assets adequately represent contributions to human well-being, (*c*) equity issues, and (*d*) uncertainty.

5.1. Strong Versus Weak Sustainability

One issue central to debates about sustainable development revolves around the substitutability of different forms of capital and the notions of strong versus weak sustainability (72). Strong sustainability requires that all major classes of assets are nondeclining through time. Weak sustainability only requires that human well-being is nondeclining through time. In principle, it is possible to satisfy weak sustainability with declining natural capital as long as other forms of capital can substitute for natural capital to maintain well-being. Inclusive wealth, with its focus on nondeclining well-being without reference to particular stocks, is firmly aligned with weak sustainability. In fact, the empirical results in Section 4 found cases of increasing inclusive wealth despite declining natural capital, and other researchers have noted that some forms of natural capital have declined at the same time that standards of living have improved (6–8). Supporters of strong sustainability, including many ecological economists and natural scientists, argue that some forms of natural capital are essential (critical natural capital) for which there is no substitute (73).

The degree of substitutability between natural capital and other forms of capital is an empirical question. Weak sustainability (inclusive wealth) does not necessarily imply there are unlimited substitution possibilities. If some form of capital is essential for well-being, then analysis of both weak and strong sustainability will come to the same conclusions on the need to preserve this essential capital. In practice, an important step to ensuring sustainable development is to understand and conserve essential natural capital in the spirit of strong sustainability.

5.2. Do Prices Represent Contributions to Well-Being?

Inclusive wealth is defined in terms of the value of capital assets. Prices are the weights placed on various capital assets that allow determinations of whether inclusive wealth is increasing even if some form of capital is declining. Using a biased set of prices risks sending distorted signals about inclusive wealth and whether it is increasing or decreasing through time.

As discussed in Section 2, in principle the price of a unit of a capital asset is the present value of the flow of increased benefits owing to the existence of the asset. In other words, the price of a capital asset represents its contribution to present and future well-being (11, 12, 27, 74). But many researchers question whether prices of capital assets are accurate signals of current and future well-being in practice.

The most straightforward critique of using prices as signals of value is that they can be distorted by various types of market failure, such as imperfect competition, imperfect information, externalities, or public goods. The consideration of externalities and public goods is especially relevant for valuing natural capital. Many ecosystem services generate significant externalities so that prices are not reflective of their contributions to well-being or are public goods for which there may be no market price at all. The inclusive wealth framework accounts for these challenges in theory, and in fact, much of the impetus for inclusive wealth was to expand what was included in the economic accounts to adequately reflect externalities and public goods. Economists have devised various methods for estimating nonmarket values when prices are badly distorted or where there is no market price (75). However, accurate estimation of nonmarket values remains a central focus of environmental economics, and more work remains to be done in capturing the nonmarket values of ecosystem services and natural capital (76).

More profound challenges to using prices as a measure of well-being come from research results in psychology and behavioral economics. Many empirical studies have found systematic deviations between the type of rational agent assumed in economic models and the often seemingly irrational behavior of real people (77–82). Human decision making is subject to various biases that may lead to a divergence between observed choices and well-being. For example, the literature on preference reversals shows that people's behavior does not necessarily reflect their stated monetary values for different options (81, 83). If prices do not reflect underlying values, then there is no guarantee that nondeclining inclusive wealth means nondeclining human well-being.

As in much of economics, inclusive wealth assumes that well-being can be assessed in terms of preexisting individual rankings (based on utility functions) over outcomes. In contrast, some research indicates that preferences do not exist independent of context but rather are developed through the deliberative process of decision making (84). In this case, a participatory process may be required to develop meaningful sustainable development metrics (85, 86). Some analysts also argue for participatory processes for decisions involving incommensurable values that cannot be adequately captured in a common metric, such as a monetary value (87). A participatory process can guide stakeholders in thinking through alternatives and ultimately making a decision, which at least implicitly makes a ranking over alternatives and involves a comparison of values. However, participatory processes and inclusive wealth both suffer from the problem of information aggregation. Just as it is difficult to measure everything necessary to calculate inclusive wealth, it is also unclear what participatory process can adequately capture sufficient information to assess national and global sustainability.

Inclusive wealth also assumes that the objective of sustainable development is nondeclining human well-being through time. But some environmental ethicists have argued that other species, biodiversity, or nature in general have intrinsic values and should be preserved regardless of whether or not they contribute to human well-being, similar to arguments for strong sustainability (88, 89). Arguing that nature has intrinsic value and hence must be protected is quite different from arguing for the protection of nature only if it is important for sustaining human well-being as in weak sustainability. Managing for inclusive wealth will likely lead to greater preservation of nature, but only for its instrumental value, and it will therefore not address the fundamental concerns of those who argue for nature's intrinsic value.

5.3. Equity

Sustainable development is motivated by the issue of providing for the well-being of future generations. As such, sustainable development has a strong element of intergenerational equity built in. To the extent that prices capture contributions to well-being, nondeclining inclusive wealth also satisfies a core notion of intergenerational equity, namely that future generations should be at least as well off as the current generation. However, inclusive wealth is a statement about the aggregate value of all types of capital for the whole of society. As such, it does not directly address questions about the distribution of wealth within a generation. It is possible for people on average to become better off even though some segments of society are made strictly worse off. So, for example, if inclusive wealth increases average well-being, but the poorest in society suffer a decline in their well-being, should this be viewed as satisfying sustainable development? Such a case would probably fail the sustainable development definition of "meeting the needs of future generations" (17).

One way to include equity considerations within the inclusive wealth metric is to use equity weights that assign a different value to gains (losses) of different groups based on their relative wealth. Groups that have low wealth have a high marginal value for increasing wealth, and the marginal value falls with increasing relative wealth. Such approaches have been used in climate change to give greater importance to climate impacts that affect low-income countries (90, 91).

An alternative approach to equity is to disaggregate wealth to see how particular groups within society are faring. Measuring the inclusive wealth for particular groups necessitates measurement of financial capital, in addition to the value of the other forms of capital, for each group. A decline in the value of some form of human, manufactured, natural, or social capital can be made up for by an increase in financial capital. A more stringent requirement for satisfying sustainable development would be to have nondeclining wealth for all groups in society. Nondeclining inclusive wealth for all groups is an extremely challenging objective. Alternatively, one could focus on improving the well-being of the worst off groups in society so that sustainable development is satisfied only if the minimum well-being is increasing through time (92). A focus on the distribution of wealth, in contrast to a sole focus on aggregate wealth, matches with recent interest in the topic of inequality in society and the concerns about the rise of inequality of income and wealth (93, 94).

It is also possible to address equity by moving even further away from assessing the wealth of various groups and instead consider needs-based (17) or capability-based approaches (95). Needs-based approaches require agreement on what constitute needs, and capability-based approaches focus on assessing the extent to which people have the effective freedom to achieve goals. As such, the needs and capabilities approaches represent a significant departure from the inclusive wealth approach and would necessitate collection of a different set of information.

5.4. Uncertainty

The value of a capital asset, at least in theory, represents the present value of the flow of current and future benefits generated by the asset. The flow of future benefits depends on future conditions. For example, the value of agricultural land depends on the likely future prices of agricultural crops. But future crop prices depend on future supply and demand, which in turn depend on future climate conditions, the evolution of pests and pathogens, future agricultural technology, future population size, wealth, and preferences. Even for this one relatively tangible asset, there are multiple sources of uncertainty that cloud the assessment of future values on which the current price of the asset depends.

The existence of uncertainty by itself is not necessarily a problem. To some extent asset prices are always determined with some degree of uncertainty. Asset prices can be found by weighing future contributions of the asset for each potential future outcome by their probability of occurrence. Doing so becomes more difficult when it is not possible to know the complete set of potential future outcomes (i.e., surprises may occur) or when there is not sufficient information to determine probabilities in a reasonable manner (96). A particularly difficult issue with the adequacy of inclusive wealth as a metric of sustainable development comes from the potential for rapid shifts in future conditions that are possible with nonlinear dynamics in complex systems (97, 98). To the extent that the risks of crossing thresholds and the consequences of doing so are well characterized, such risks could, in theory, be incorporated into the inclusive wealth framework. But when such risks or consequences are poorly understood, it is unlikely that current asset prices will adequately capture the potential consequences from crossing thresholds. Potential loss from a catastrophic change in natural capital is a risk that might warrant special attention outside of the evaluation of inclusive wealth, such as trying to assess where critical zones may occur and restricting changes in natural capital to avoid entering such zones (5).

6. SUMMARY AND DISCUSSION

Difficulties in measuring the value of various forms of capital, particularly natural and social capital, make inclusive wealth more of an ideal rather than a practical approach for defining progress toward sustainable development at present. Despite the difficulties in measuring inclusive wealth, however, the inclusive wealth approach is instructive for providing insights into what makes achieving sustainable development more or less likely, and it helps us to think clearly about sustainable development, even if it is does not yet provide a clear empirical metric for sustainable development.

The main advantage of the inclusive wealth approach is that it provides a unified and coherent framework for thinking about sustainable development. Nondeclining inclusive wealth means that the productive base available to society (the collective set of assets in the form of human, manufactured, natural, and social capital) and available to future generations will give them the capacity to provide for equal or greater well-being as compared to that enjoyed by the current generation. Inclusive wealth addresses a significant shortcoming in income-based measures, such as GDP, by accounting for changes in the productive base of assets. Inclusive wealth also makes clear what kind of information is needed to assess progress toward sustainable development, namely estimates of the amounts of various forms of capital and their likely contributions to current and future human well-being.

Trying to estimate the full value of inclusive wealth in practice, however, suffers from nearly impossible data demands. No current measure of inclusive wealth is in fact fully inclusive. Approaches building from national income and wealth accounting data do not include most nonmarket values and thereby exclude the value of much of natural capital as well as social capital. Work is underway to expand national income and wealth accounts to include more of the nonmarket values of natural capital (18, 28), and this offers some hope that national-level inclusive wealth measures will become more inclusive with time.

Another avenue toward generating a more inclusive estimate of inclusive wealth involves the use of integrated ecological and economic models. To date, such models typically have focused on a small subset of ecosystem services and mostly in local or regional applications. Ongoing efforts and recent studies have extended both the scope and scale of the values of ecosystem services (18, 25, 50, 55, 61, 62, 99, 100). To become a base for estimates of inclusive wealth, however, integrated models also need to incorporate dynamics to capture changes in natural capital as well as other forms of capital. A fully dynamic model would allow for estimation of the value of current and future ecosystem service flows, rather than focusing solely on the current value of ecosystem services. Reports of work by Bateman et al. (61) in the United Kingdom, which incorporates climate change, and Lawler et al. (62) in the United States, which incorporates long-run land-use change, illustrate two ways in which such work could proceed.

Another suggestion for overcoming measurement difficulties in the inclusive wealth approach is to aim for semi-inclusive wealth rather than fully inclusive wealth. Stiglitz et al. (30) argue that, instead of trying to summarize all relevant information in the single metric of inclusive wealth, a more practical goal would be to aim for a small set of metrics. A monetary measure of wealth could be reported for those things that can be relatively easily measured in monetary terms. This monetary metric could be augmented with a set of biophysical metrics capturing important aspects of natural capital that are difficult or impossible to measure in monetary terms. A useful analogy is the dashboard of a car that has various gauges providing useful pieces of information about the performance of the car, without attempting to combine all the information into a single overall metric of performance. A similar approach to semi-inclusive wealth is often done in benefit-cost analysis in which monetary estimates of benefits and costs are done where possible, and nonquantitative benefits or costs are included where it is not possible to monetize or quantify benefit or costs (101, 102). In addition, a semi-inclusive wealth approach represents something of a middle ground between a metric of weak sustainability and strong sustainability.

Over time and with further research the semi-inclusive wealth measure will become more inclusive as we better understand how to measure and value various forms of capital. At present, combining measures of inclusive wealth with indicators of changes in critical natural capital seems to provide a sensible approach to providing a set of signals of whether society is proceeding along a sustainable development trajectory.

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Errata

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