Reflections—Defining and Measuring Sustainability

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Introduction

There is a saying in business schools that "what gets measured, gets managed." This is bad news for managing our natural capital and the interactions between our economic activity and the environment, which are key to sustainability: these are almost entirely unmeasured and often unmanaged too.

None of the usual measures of economic performance—gross domestic product (GDP), unemployment, inflation—tell us anything about the state of our natural capital. In fact, they can be downright misleading.[1] For example, some parts of India are running out of water, and the water table is falling. Farmers have to drill deeper wells to find water, using more labor and energy. But because this extra spending raises GDP, water shortages appear to be raising India's GDP and making the country better off. While the water shortages are indeed raising economic activity in a macroeconomic sense, more important is the fact that they are a threat to growth in the future: when it is no longer possible to find more water by drilling deeper, agricultural output will collapse and welfare will drop.

So we are missing a warning sign here—the falling water table—and wrongly interpreting it as contributing to growth.

In fact, there is little in our normal economic statistics that would warn us of an impending environmental crisis. We might be warned we are about to run out of oil by high oil prices or out of soil by high food prices, but for a broad range of environmental goods and services, there are no markets, no prices, and hence no signals in the market system to warn us of potential problems.

Can we improve on this? That is the main question I address in this review of the literature on sustainability. This requires not only a discussion of the alternatives to GDP but also an examination of the concept of sustainability and the possibility of quantifying it.

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[1]For a more general critique of GDP, see Stiglitz, Sen, and Fitoussi (2010) and the pioneering work of Nordhaus and Tobin (1972).

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Alternatives to GDP

What changes could we make in our measures of economic performance that would improve on GDP so that it provides an accurate signal about our environmental performance?

Net Domestic Product

One relatively simple move, at least conceptually, would be to move from GDP to net domestic product (NDP). The difference between these two measures is that the depreciation of capital is subtracted from GDP to arrive at NDP. However, as the national accounts currently exist, the capital whose depreciation is subtracted is physical capital, the only type of capital currently measured.

So subtracting the depreciation of physical capital converts GDP to NDP, which is really a better measure of what the economy is producing and making available to its members. The reason we currently use GDP rather than NDP is purely pragmatic: it is hard to measure depreciation of capital accurately. Our knowledge of depreciation comes largely from how assets are written down for tax purposes, and depreciation rules in tax codes are arbitrary, reflecting more the outcome of political lobbying than economic analysis. As a result of being depreciated over relatively short time frames, many assets are carried on corporate balance sheets at almost no value when, in fact, they are still nearly as valuable as when they were new. True economic depreciation, of course, is the loss of economic value, which for an asset is the decline in the net present value of the services it can provide in the remainder of its life.

From an environmental perspective, the difference between GDP and NDP is important because much of the impact of human activity on natural capital can be thought of as depreciating this capital, reducing it in amount or value. A simple example is Saudi Arabia, which makes its living by extracting and selling oil. Oil is a form of natural capital, so Saudi Arabia is running down its natural capital. Each year its stocks of oil are lower than they were the previous year, with the decrease representing the depreciation of the country's natural capital. The depreciation of this capital is the value of the oil that Saudi Arabia sells. This means that if we were to calculate its NDP by subtracting the depreciation of natural capital from GDP, it would more or less cancel out Saudi Arabia's income from the sale of oil, which is most of its income, and would thus leave the Saudis poor.[2]

The point here is that NDP is a better measure of output than GDP, particularly if we want to measure and value changes in natural capital. However, while NDP is clearly an improvement on what we use today, it by no means provides an answer to the question "What should we measure?"

Human Development Index

Some people have sought to address this question by moving away from a money-based income measure altogether and instead constructing something that tries to measure the well-being of members of a society more directly. The best known of these measures is

[2]For an early discussion of this point, see Repetto et al. (1989) and Dasgupta and Heal (1979).

the human development index (HDI), developed and published by the United Nations Development Program (UNDP). The HDI is based on data in three areas—health, education, and income—which UNDP sees as the key dimensions of welfare. More specifically, for each country, UNDP collects data on life expectancy at birth, mean years of schooling, and average income per capita, and, by taking the equal-weighted geometric mean, combines them into a single number, the country's HDI score. The HDI does not address environmental issues but could provide a model for nonmonetary measures that include environmental data, some of which have been developed recently.[3]

Gross National Happiness

An intriguing variant on the conventional approaches to measuring economic performance is found in the small Himalayan kingdom of Bhutan, where economic and social performance is measured by the index of gross national happiness (GNH).[4] The country's Buddhist culture influenced its decision to move toward a more spiritual measure than GDP with its exclusive emphasis on material possessions. GNH tries to take into account performance across nine dimensions: psychological well-being, time use, community vitality, culture, health, education, environmental diversity, living standard, and governance. Environmental diversity, intended to be a measure of the health of natural capital and ecosystems, is measured by the level of afforestation or deforestation and some other measures of environmental degradation. Time use is a measure of how much time is available for nonwork activities such as recreation and time with family and friends. It also measures the time devoted to volunteer activities that help the community. Community vitality is an attempt to measure trust, reciprocity, how safe people feel, and how closely connected they feel to others.

The intentions behind GNH are clearly excellent; it's difficult to fault them. If there are problems, they lie in the execution of the GNH: Is it in fact possible to measure these concepts? How do we combine the results of measurement into a single number? And, in particular, could this measure be calculated for a country the size and complexity of the United States?

Adjusted Net Savings

Adjusted net savings (ANS) is one of the better measures of sustainability and may provide the kinds of warnings of impending environmental crisis that, as we noted earlier, conventional economic statistics fail to deliver. To calculate ANS, we start with a conventional measure of net investment in plant and equipment, that is, investment net of depreciation. We add to this investment in human capital through education and investment in intellectual capital through research and development (R&D), and then we subtract the depreciation or degradation of natural capital. The World Bank (World Bank 2006, 2010) produces figures for the ANS for each country, but the data are also available on the UNDP web site (http://hdr.undp.org/en/statistics/). I explore and discuss ANS in more detail later in connection with sustainability issues.

[3]See, for example, the CIESIN Environmental Sustainability Index (CIESIN n.d.).
[4]For more information, see the Bhutan government web site at http://www.gnhc.gov.bt/.

Relative Performance of Selected Countries

To offer some sense of what these different measures of economic performance look like when they are applied to individual countries, figures 1, 2, and 3 show GDP per capita, the HDI, and the ANS for six countries: the United States and Germany (two leading industrial countries), China and India (the two preeminent emerging economies and leaders in the BRIC group [Brazil, Russia, India, and China]), and Botswana and Papua New Guinea (two very different small developing countries).

Figure 1 indicates that for all six countries GDP per capita has risen over the last thirty years. However, the implications of this income growth for the well-being of the average citizen are far from unambiguous (see Stiglitz, Sen, and Fitoussi 2010). Figure 1 also indicates that the United States and Germany are far richer than the rest, and it also shows very clearly that Botswana is much richer—in GDP terms at least—than either China or India.

Moving to figure 2, although the HDI measure is totally different from GDP, it actually tells a rather similar story. All countries have again improved their performance over the thirty-year period. The two richest countries are still at the top, although they are much closer together than for the GDP measure. Here China ranks on a par with Botswana, and India and Papua New Guinea are again at the bottom.

Moving to figure 3, which shows trends in ANS as a percentage of gross national income, we see a completely different picture: Botswana dominates the top ranking, with China second. The United States and Germany do not fare well, indicating that being rich is perhaps not the same as being sustainable. This is a good lead-in to the issue of sustainability, which is the focus of the remainder of this Reflections.

The Notion of Sustainability

When it comes to human well-being, we might ask two distinct questions: first, how well off are people now, and how is this level changing over time? And second, can current levels of

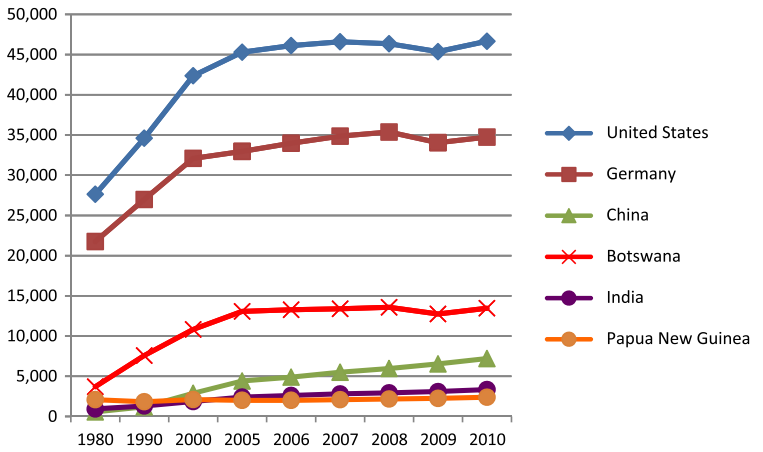

Figure 1 GDP per capita for selected countries, 1980–2010 ($US 2010)
Source: United Nations Environment Program web site, UNDP.

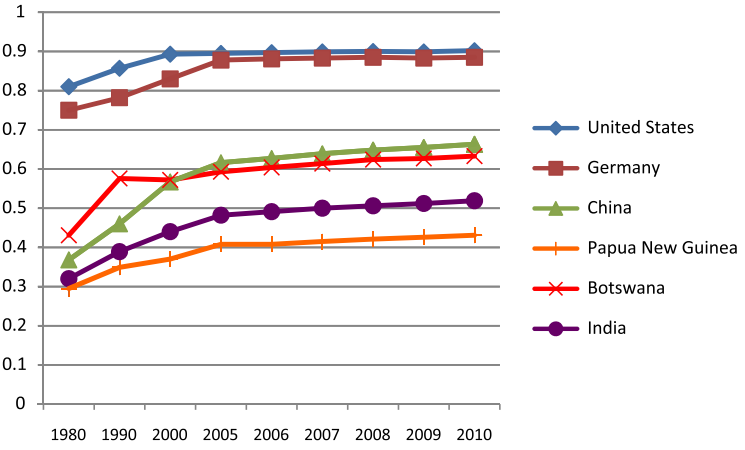

Figure 2 HDI for selected countries, 1980–2010
Source: United Nations Environment Program web site, UNDP.

well-being be sustained over time? That is, will our successors be able to live as well as we do? GDP (and its various refinements) and the HDI (as shown in figures 1 and 2) are attempts to answer the first question. The second question leads to a discussion of sustainability, which, to some degree, is captured by ANS (figure 3).

Sustainability is a buzzword these days. Everyone and everything wants to be perceived as sustainable. However, analytically, the issue of whether or under what circumstances growth can continue, or whether it will be limited by environmental and resource constraints, is not new. It was addressed extensively in the 1970s in the literature on exhaustible resources (see Dasgupta and Heal 1974, 1979; Hartwick 1977; Solow 1974; Stiglitz 1974) and indeed dates all the way back to Malthus (1798/1993). But it's especially topical today because it is becoming more evident that the scale of human activity is now sufficiently great as to affect the operations of global biogeochemical systems, with the carbon and nitrogen cycles obvious examples, and thus the future of life on earth.

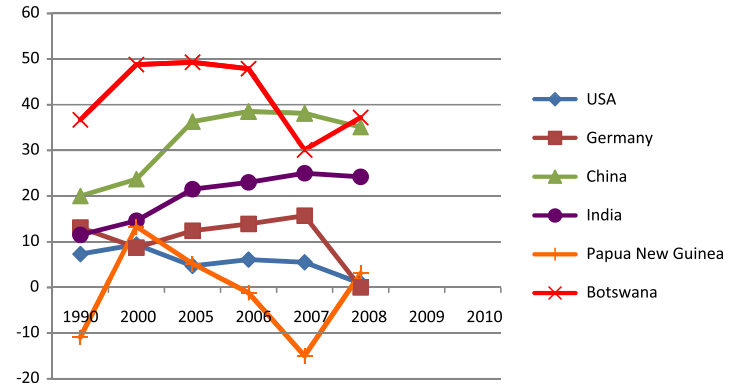

Figure 3 ANS as percentage of gross national income for selected countries, 1990–2008
Source: United Nations Environment Program web site, UNDP.

Some country examples will help to illustrate the issue of sustainability. I focus here on Botswana, Namibia, and Saudi Arabia, which are good countries to think about when trying to understand sustainability.

Botswana and Namibia

Botswana and its neighbor Namibia share a long common border and are similar in many ways: both are arid or semiarid and in the southern cone of Africa. Botswana's population is about 1.8 million, and its land area is 600,000 square kilometers, slightly smaller than Texas. Namibia has a population of 2 million and a larger land area, 825,000 square kilometers. Namibia has a long coastline on the Atlantic Ocean and a major fishery, whereas Botswana is landlocked. Both are largely desert, Botswana being dominated by the Kalahari Desert and Namibia by the Namib.

Botswana has one truly remarkable feature, the Okavango Delta in the north. The Okavango River is the only large river in the world not flowing into a sea: instead it flows into the Kalahari Desert. A huge river rising in the Central African highlands and flowing into one of the hottest deserts on earth is a stunning phenomenon. It creates a unique environment, amazingly rich in species. The environment varies, from aquatic where the river first reaches the desert, home of crocodiles and hippos and a range of fishing birds, to semiarid scrubland on the fringes of the areas irrigated by the river. The Okavango Delta is a natural asset that provides the basis for Botswana's immensely successful ecotourism industry, with thousands of high-paying visitors each year. Namibia has some remarkable landscapes too, especially the skeleton coast area in the north, and a growing ecotourism industry. Both are well worth a visit!

In addition to having the kinds of natural environments that support ecotourism, both Botswana and Namibia are rich in minerals. Botswana has huge deposits of gem-quality diamonds. Namibia also has diamonds, although fewer than Botswana, but in addition it is rich in uranium, lead, tin, zinc, silver, and tungsten. The long Atlantic coast also provides large fishing grounds.

Both countries are generating income by depleting natural capital (their diamonds, uranium, lead, fish, etc.), but they are also generating ecotourism income from their unique biodiversity. Thus they could offset their depletion of natural capital by building up holdings of other forms of capital, or they could let their total stock of capital assets fall. As it happens, Botswana is doing the former while Namibia is doing the latter.[5] As shown in figure 3, Botswana is a paragon of sustainability, building up both its human and physical capital. In fact, Botswana is one of the developing world's success stories, a much needed Africa success story. Its living standards have grown consistently and rapidly since independence in 1966, making it a middle-income country rather than a poor one, and it is also a very successful democracy. As we will see later, Namibia has been less successful in both accumulating capital and raising income levels.

[5]Namibia's unsustainable practices began when it was ruled by South Africa under a UN mandate dating from the end of the Second World War and the defeat of Germany, the former colonizer. The preintegration South African regime treated Namibia as a storeroom to be emptied rather than a country to be developed.

Saudi Arabia

The ultimate country example of unsustainability is Saudi Arabia. It is rich, certainly, but not sustainable, again illustrating that being rich and being sustainable are two very different concepts. Saudi Arabia makes its living by selling oil reserves, in effect selling off the family silver. Eventually, although not in the near future, as its reserves are huge, it will run out of oil and gas. Then there will be nothing to pull from the ground and sell, and unless Saudi Arabia has built up some other forms of capital, its living standards will suddenly collapse. Clearly, its living standards are not sustainable in the long run.

Defining the Concept of Sustainability

A lifestyle, a way of doing things, is sustainable if most of the world's population could continue it for a long time without major adverse consequences. That is, it is a potential dynamic equilibrium of some type.[6] Our current patterns of energy use are not sustainable: they produce greenhouse gases, changing the climate and leading to threats to our lifestyles and even our civilization. Our current patterns of agricultural production are probably not sustainable either: they lead to loss of soil and massive pollution of waterways by fertilizers, are threatened by a changing climate (see Schlenker, Fisher, and Hanemann 2005), and probably depend on levels of water availability that will not continue. Our current patterns of water use are not sustainable: we are depleting underground water faster than it recharges and polluting surface water. And our current levels of fish catch are manifestly unsustainable: they will destroy key fish populations within decades. In analytical models, sustainability is generally defined, as we will see later, in terms of the potential to maintain current living standards well into the future.

The Brundtland Report (1987),[7] written for the United Nations by a committee chaired by Dr. Gro Harlem Brundtland, the former prime minister of Norway, defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Although vague, this does make one point clear: there is an intergenerational aspect to sustainability. That is, we could live well now but ruin the earth in the process and pass on to our successors a world that is greatly diminished, as the current patterns of resource use discussed in the previous paragraph suggest we may be doing. The Brundtland idea of sustainability urges us not to do this. This idea of responsibility to later generations is often interpreted as meaning that we should leave them enough assets to be as well off as we are. This goal is built into the idea of ANS. Thus I consider ANS in more detail toward the end of this article because it can tell us whether we are actually leaving enough for future generations to be as well off as we are. In the remainder of this section I talk about natural capital and the role it plays in sustainability.

[6]For analytical discussions of the concept of sustainability, see Heal (1998) and Neumayer (2010).
[7]Formally the report of the World Commission on Environment and Development (1987).

Trading Natural for Physical and Intellectual Capital

There is another dimension of sustainability, omitted by the Brundtland definition, that has to do with the natural environment. The natural environment—or natural capital—is of immense value to human societies. We depend on it in many ways, and there are services it provides that are likely irreplaceable (see Daily 1997 and Heal 2000). A lot of our activities, those that damage the environment, are depleting this natural capital, running it down so that future generations will inherit less and poorer natural capital: a world with a less stable and hospitable climate, fewer species, less water, and less of many other environmental assets. It is this environmental damage and depletion of natural capital that may be making our activities unsustainable and perhaps condemning our successors to an impoverished lifestyle.

To be fair to ourselves, while we are leaving future generations less natural capital than we inherited, we are leaving them more than we inherited in terms of built capital: more freeways, airports, buildings, and infrastructure. We are also leaving them more intellectual capital than we inherited: our R&D programs are developing cures for diseases, new products, and new ways of doing things. In only the last twenty years the Internet and wireless communications have come from nowhere to dominate our lifestyles: we will hand these on to our successors, together with other things not yet invented, perhaps offsetting or compensating for the depleted environment that we are also leaving them.[8] Thus the composition of humanity's portfolio of capital stocks is changing, away from natural capital and toward other forms of capital.

Will this compensation for the loss of natural capital be adequate? Can we compensate for a depleted natural environment by more of the fruits of human labor and ingenuity? So far we certainly have: we are by general consent far better off than our predecessors a century ago. But what has happened in the interim is that we have built up our intellectual and physical capital massively while at the same time we have run down our natural capital. We have lost forests, rangelands, and quite a number of species, but we have gained cures for common diseases, acquired central heating and air conditioning, domestic appliances, cell phones, laptops, and the Internet. We have traded Spix's macaw, the Chinese freshwater dolphin (the Baiji), and other unique species for the iPhone and other (not so unique) gadgets. Most of us are probably not unhappy with this deal. So it appears that to date we have been able to compensate ourselves for declining natural capital by amassing more of the fruits of human labor and ingenuity. Can we continue this way? Can we maintain or increase our well-being if we continue trading natural environments and endangered species for better technology and infrastructure? This is the crux of the sustainability issue.[9]

It seems likely that matters are changing and that in the future we will not in fact be able to compensate for the loss of natural capital through the accumulation of other forms of capital. Climate change is a new phenomenon, not something we were aware of a century ago. It has grown to prominence with the massive expansion of fossil fuel use in the twentieth century,

[8]For a very clear documentation of these trends in the composition of capital stocks, see World Bank (2006, 2010).

[9]It is also possible that future people will value these natural assets differently from us—perhaps more as they will be scarcer, perhaps less as they will be used to a more synthetic world. On this see Beltratti, Chichilnisky, and Heal (1998) and LeKama and Schubert (2004).

will lead to changes that are qualitatively quite different from those resulting from past economic activity, and within the relatively short time frame of the next few decades could inflict substantial costs on the world. The current rate at which we are losing species is also without historical precedent: while we have driven species to extinction in the past (the dodo and the passenger pigeon are examples), we have never threatened as many species with extinction as we are doing today. Forests are being cleared at a rate unprecedented even in the times of the Industrial Revolution when wood was the principal fuel. We are also having a dramatic and negative effect on the oceans: the populations of large fish in the sea—the ones we eat—are claimed to be down to about 10 percent of what they were only half a century ago.[10]

The bottom line here, then, is that we are depleting our natural capital faster than ever before, and we have already depleted it to a greater extent than ever before. We depend on it, we need it, and our current lifestyle will not survive without it. So it is not clear that the old trade-offs will continue to work, that we can compensate for the loss of natural capital as we have in the past by adding more and more intellectual and physical capital.

Compensating for the Loss of Natural Capital: Some Case Studies

It is interesting to look in detail at this issue of compensating for the loss of natural capital with the buildup of other forms of capital by examining some specific cases. Again, Saudi Arabia is a good example. Let's look at some numbers to get a rough idea of the magnitudes involved. Saudi Arabia produces roughly 10 million barrels of oil per day and has a population of about 25 million. At its peak, oil was selling for about $130 per barrel, although this is much higher than the average price for the last few years, which is below $100. In any case, at the high price of $130 per barrel, Saudi annual oil revenues amount to just under $19,000 per capita. That is to say, if the total oil revenues were divided equally among all Saudis, then each would receive about $19,000 per year. A family of four would have just under $80,000. Not superrich, but not bad for not working. At a price of $60, much more typical of prices over the last few years, each person would get $8,700, making about $35,000 for a family of four. When Saudi Arabia's oil runs out, this income will suddenly cease, and there will be nothing to replace it, unless some of the revenue from oil has been invested in a way that can replace oil as a source of revenues. For example, a fraction of the oil revenues could have been invested in shares and bonds from around the world, yielding a flow of dividends and capital gains to replace the income from oil when the time comes. If enough were invested to replace all the oil income, then Saudi Arabia would be running its economy sustainably. Alternatively, Saudi Arabia could invest income in productive assets such as factories and in the education of its people. This too could generate a source of income that could replace oil revenues in due course.[11]

In contrast to Saudi Arabia, there are oil-producing countries or regions that are trying to run their economies sustainably. Two good examples are Norway and Alaska, through the Norwegian State Petroleum Fund and the Alaska Permanent Fund, respectively. Both of these funds are set up to take revenues from the sale of oil and invest them to provide a long-run income source that will continue even after the oil reserves are depleted. In the case of the

[10]There is some dispute about the accuracy of this claim: see Myers and Worm (2003) and Sibert et al. (2006).
[11]For more discussion of these issues, see Heal (2007).

Norwegian State Fund, revenues for investment come from the government's 80 percent share in Statoil, the Norwegian oil company that develops the country's North Sea oil fields. This fund now has $147 billion invested. The Alaska fund receives about 25% of oil and gas royalties, and it now has accumulated about $28 billion. It pays an annual dividend to all Alaska residents, averaging over $1,000 per year per person and peaking at $1,800. In both cases, what we are seeing is the conversion of natural capital—oil is a form of natural capital—into financial capital. The financial capital can continue and yield dividends after the natural capital is fully depleted. So these are both examples of countries or states compensating for the loss of natural capital by the accumulation of another form of capital.

It's worth thinking briefly about this from an accounting perspective. Think of the country's statement of assets and liabilities. Initially its assets consist largely of natural capital. Then over time this is depleted and the value of the asset falls. If this were all that happened, then the total value of the country's assets would fall. But if the revenues generated by the depletion of natural capital are invested in financial capital, a new asset appears on the balance sheet, the financial capital assets of the investment fund, and the buildup of these assets offsets to some degree the rundown of the natural capital assets. If well managed, this approach could keep the total value of the country's assets constant. Alaska and Norway may be doing this, but Saudi Arabia clearly is not.

Botswana offers another example of a country trying to run its economy sustainably, with the government deliberately investing a significant part of the revenues from diamond mining in physical and human capital (see Lange 2004 and Lange and Wright 2004). Both wealth per person and income per person have roughly tripled in Botswana in the last twenty years. In contrast, both wealth and income per person have declined in neighboring Namibia. Much of Botswana's success is due to its policy of consciously using revenues from natural capital to build up physical and other forms of capital, following the Hartwick (1977) rule. Lacking any explicit policy of using revenues from natural capital to build up other forms of capital, Namibia has seen declines in its total capital stock, the total value of its assets, and its per capita income. Figure 4 illustrates this contrast between Botswana and Namibia.

Back to Trade-offs

What do these cases tell us about sustainability? In the case of mineral resources, they suggest that basing an economy on running down natural capital need not imply unsustainable income levels. A country can compensate for the depletion of this type of natural capital by investing in other forms of capital, keeping its balance sheet intact and replacing one asset with another. The key question that this discussion raises is whether this is also true for the depletion of forms of natural capital other than mineral resources. That is, can we expect to compensate for the loss of aspects of the climate system, or the hydrological cycle, or our biodiversity or tropical forests, by building up more of the kinds of assets that we produce—physical or intellectual capital? Can the accumulation of physical and intellectual capital enable us to adapt to climate change, in the sense of maintaining our living standards in the face of an altered climate?

This is a controversial question. The basic issue here is the extent to which the services of capital constructed by humans can replace the services provided by living natural capital. Can we create substitutes for what we get from nature? In the limit, the answer has to be no. We

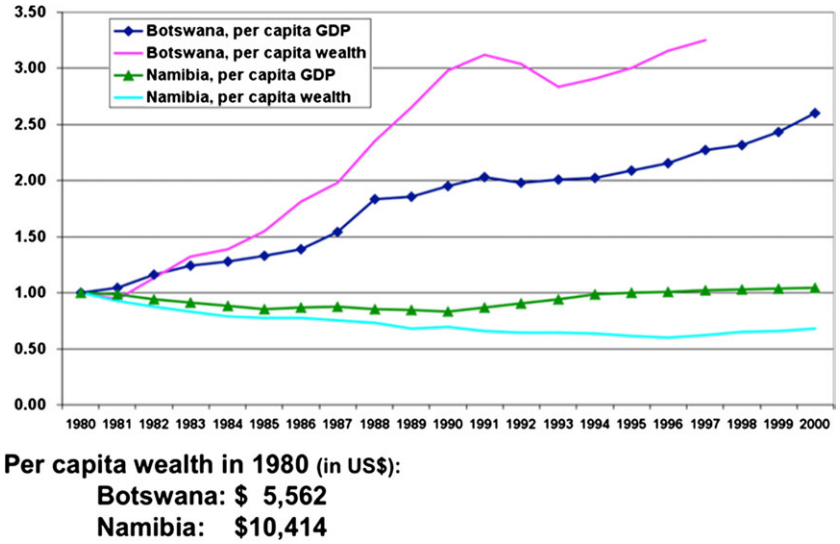

Figure 4 Index of real, per capita GDP and wealth in Botswana and Namibia, 1980–2000
Source: Lange (2004).

need oxygen—it's what powers our bodies. Oxygen is produced by photosynthesis, carried out by plants and by photosynthetic algae in the oceans, so we can't replace them as a source of oxygen. Food is also something whose production depends on the services of natural ecosystems: it depends on the productivity of soil, a complex ecosystem easily damaged by overuse; on the climate, determined in part by the complex worldwide carbon cycle; and on the actions of agricultural pests that attack food crops, as well as their natural predators, such as birds and bats, that keep these pests under control.

Clearly, we cannot replace all aspects of natural capital with physical or financial or intellectual capital. Mineral resources are just wealth: they provide their owners no other services than the wealth they generate in the market. So we can compensate for their depletion by building up our wealth, along the lines of Alaska, Norway, and Botswana. In the case of forests and coral reefs, and ecosystems in general, however, which provide more than just wealth, they cannot be fully replaced by financial assets or physical capital. New York City came to this conclusion when it chose to conserve the Catskill watershed, and it's what the Chinese government concluded when it chose to stop deforesting watersheds and instead moved to an aggressive program of reforestation: there was no real cost-effective substitute for natural capital in the form of forests and riverine ecosystems (see Heal 2000). What matters here are the elasticities of substitution between the various types of capital, both in production and in welfare functions. I am suggesting that for certain types of natural capital, this elasticity is less than one, implying that some minimum quantity is needed to maintain well-being, an idea modeled in a preliminary way in Heal (2009).

So sustainability requires that we keep some of our natural capital intact, as it provides services that matter to us and that we cannot replace. But there are other parts of natural capital that we can safely deplete because we can replace them with money or other assets we can produce. It is largely the living aspects of natural capital that are in the first category,

exemplified by species and forests. And it is the inanimate natural capital that we can do without because we can replace it with something else. Ironically, from the way markets are working at the moment, one would think we had reached the opposite conclusion, since mineral resources, and oil in particular, are valued very highly, and biodiversity and forests almost not at all.

Weak or Strong Sustainability?

Sustainability comes in two varieties, weak and strong (see Neumayer 2010). So far, I've implicitly been talking about the former, weak sustainability. We are weakly sustainable if what we are doing will let future generations achieve our living standards or better—if we are not compromising the ability of future generations to meet their needs—which is the core of the Brundtland definition of sustainability. This is a common and totally plausible interpretation of the idea of stewardship and responsibility to future generations. But it does not incorporate any concept of stewardship of and responsibility toward the natural world and the other species with whom we share it, which is at the core of strong sustainability.[12]

As a consequence, not everyone is convinced we should be choosing the "weak" definition of sustainability. In particular, there are environmentalists who believe that natural capital itself, or at least the animate part of it, should be sustained, and that the constancy of this form of natural capital should be our criterion of sustainability. Sustainability for them means sustaining all forms of life on our planet, not just maintaining our own living standards, which they see as a narrow-minded and parochial goal. They see us as having an ethical responsibility to all life-forms on earth and not just to our own life-form. As the dominant species on earth, their argument goes, we owe it to other species, whose destinies are in our hands, to allow them to survive and prosper too.

In analytical terms, the relationship between weak and strong sustainability depends on the elasticity of substitution between animate natural capital and other forms of capital: if this elasticity is small enough, then the two concepts are not that different, whereas if it is large, then they are very different, and maintaining welfare levels does not require maintaining species.

Ultimately, the choice between weak and strong sustainability is a personal one: should we be seeking to conserve human living standards or to conserve all life-forms, or perhaps both? The former implies that we value the animate part of natural capital, biodiversity in essence, only insofar as it contributes to human welfare, whereas the latter implies that we value other life-forms in their own right.

This is an important distinction. The U.S. Endangered Species Act specifically seeks to save species from extinction even if there is no economic benefit to doing so: it reflects the belief that species have a right to exist independent of their value to us, a position taken by an increasing number of people who feel this is an issue on which they have to take a moral stance.[13] Personally, I sympathize with them, agreeing that we do not have the right to

[12]Economists have studied both concepts of sustainability and have called maintaining animate natural capital intact "strong sustainability" and maintaining human living standards "weak sustainability."
[13]Goble (2006) and Callicott (2006) develop this point further.

condemn other species to oblivion. I also believe that it's economically unwise to do so, so that to me, the two arguments move in the same direction.

Clearly, the world is not currently sustainable in the strong or ethical sense: this requires maintaining animate natural capital intact, which in turn requires not causing the extinction of other species. We are failing on this criterion. Whether we are succeeding or failing on the other criterion, namely weak sustainability, or keeping total capital intact and maintaining human welfare, is more of an open question.

Measuring Sustainability

Recall the adage "what gets measured, gets managed." So we need to be able to measure how sustainable or unsustainable our policies and institutions are.

There is, unfortunately, no way that GDP can indicate whether an income level or lifestyle is sustainable. For that we need to look at something quite different: how total wealth is evolving, where total wealth means the total value of *all* capital stocks—natural capital, physical capital, intellectual capital, and any other forms of capital that are relevant.

Measuring Income

We think of income as the return on wealth or on accumulated assets; it's the flow of payments or services from our wealth. Back in the 1930s, John Hicks defined income as "The maximum you can spend this month, consistent with spending the same in all subsequent months." This is a clever definition: it has an element of weak sustainability built in. According to this definition, Saudi Arabia's oil revenues are not income, as the oil will run out, but the earnings of the Norwegian sovereign wealth fund are income because they will be there in all future periods.

There is a subtle point here that we need to examine carefully. I noted earlier that there are some aspects of natural capital that we probably cannot replace, particularly its animate aspects, such as species and rain forests. If this is true, in what sense can we be sure we have a sustainable economy if the total value of the capital stock remains constant? After all, this constancy of the total could conceal a falling stock of animate natural capital and growing stocks of physical and intellectual capital, with the latter two replacing the former. The falling stock of animate natural capital could be compromising our ability to produce foods and medicines and stabilize the climate. I come back to this point later.

Measuring Wealth and Establishing Prices

When we talk about wealth, the total value of the stock of all types of capital, we are talking about a monetary or dollar value. For physical capital, this is relatively easy: we can find prices for items of capital equipment and then use these to value them. Intellectual capital is harder to value, although there are instances in which a value is clearly placed on ideas. For example, a firm may buy a patent from another: that is buying intellectual capital and is a process that puts a price on the intellectual capital that is transferred.

There are also situations in which natural capital is bought and sold; mineral rights, for example, can be traded. Soil is a form of natural capital that is partly mineral and partly

animate—there are complex microbial and invertebrate ecosystems in soil that account for its productivity—and it is also bought and sold when land or farms are traded. So there are forms of natural capital, even living natural capital, in which there is a market and for which we can find prices. But there are certainly other types of natural capital for which there are no prices. Biodiversity, for example, is both an important component of natural capital and one for which there is typically no market and no prices. In a case like this, we need to calculate shadow prices, reflecting the value of the resources to society. This is, in fact, exactly what prices will reflect in a well-functioning competitive market. So, in computing a society's total wealth, we can value its natural capital either by market prices, if there are active and competitive markets, or by shadow prices otherwise.[14]

Impact of Scarcity on Prices

It's important to understand the effect of scarcity on the price or shadow price of a critically important form of natural capital. If some form of animate natural capital is truly essential to us, such as watersheds and the services they provide, and is becoming very scarce, then its shadow price will rise sharply. This is the possible resolution to the difficulty noted earlier, that constancy of the value of total capital could mask a decline in important types of natural capital that are essential to our continuing well-being. If one unit of this essential natural capital has a huge shadow price—say $1 billion—and we lose one unit of it, then to keep the total value of wealth constant, we would need to compensate with $1 billion of built or intellectual capital. And if the essential natural capital were to become even scarcer, then we might need even more of other forms of capital to make up for the loss of one unit. So eventually, the essential natural capital will be so scarce and its value so high that it will be impossible to compensate for its loss by adding more of other forms of capital, and the total value of wealth will fall. This would indicate nonsustainability.

More on ANS

Figure 3 illustrated a widely used measure of sustainability that attempts to measure the change in a nation's total wealth, ANS. Developed by the World Bank (see World Bank 2006, 2010; Hamilton and Hartwick 2005), ANS is, in principle, a measure of the total change in the value of all of a nation's capital stocks—physical, natural, intellectual. If it is positive, the country is sustainable, and if negative, it is not sustainable, at least in the sense of weak sustainability.[15] The formal proposition behind my interest in ANS is the following. Along a time path that satisfies the first-order conditions for dynamic optimality, an economy's state valuation function, which is the present value of all future welfare levels, is nondecreasing at time t if and only if ANS is positive at time t. This means that the economy's future is getting better, or no worse, if ANS is nonnegative.[16]

[14]For a more extensive discussion of the valuation of natural capital and the services that it provides, see National Research Council of the National Academies (2005).
[15]There is some complex theory behind this statement. See, for example, Heal and Kristrom (2008), Hamilton and Hartwick (2005), and Arrow, Dasgupta, and Mäler (2003).
[16]See Heal and Kristrom (2008) and the earlier references therein for more details.

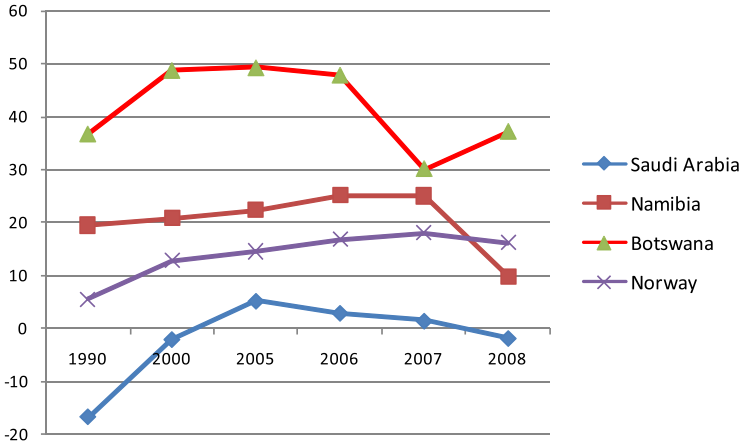

Figure 5 ANS for Botswana, Namibia, Norway, and Saudi Arabia, 1990–2008
Source: UNDP web site.

Figure 5 presents more ANS data, showing the movement of ANS as a percentage of GDP over time for Botswana, Namibia, Saudi Arabia, and Norway. Botswana's ANS is always the highest of the four, whereas Saudi Arabia actually has a negative ANS for much of the time. From the earlier discussion, we know why this is the case. Namibia, very similar to Botswana in many ways, has been much less effective in building up its capital stocks, although its ANS is still quite positive. Norway has a steadily positive ANS, in spite of the fact that its economy, like that of Saudi Arabia, is based on depletion of natural capital.

Let me end by emphasizing that when we discuss the constancy of total wealth as indicating sustainability, we are referring to the sustainability of living standards (i.e., weak sustainability). This was the focus of the Brundtland definition, which spoke of the ability of the present generation to meet its needs without compromising the ability of future generations to do likewise. However, in this context, we are not indicating whether living natural capital is being maintained at a reasonable level.

Conclusions

Where does this leave us in our overall assessment of sustainability and its measurement? First, the concept of sustainability clearly matters: we need to know whether we are compromising the abilities of future generations to live as we live. Second, we need to know whether we are sentencing a large fraction of life on earth to death to the power two, that is, to extinction and complete obliteration. Both issues matter and on the surface appear to reflect somewhat different interpretations of sustainability. But some researchers, particularly in biology and ecology, claim there is in fact no difference between these weak and strong interpretations of sustainability, that any world in which many species are obliterated will be one in which humans suffer too. In economic terms, these researchers are saying there is limited substitutability between some types of natural capital and other forms of capital (see Ehrlich and Goulder 2007).

Where are we when it comes to measuring sustainability and judging whether we are managing our affairs in a sustainable fashion? The report of the Commission on the Measurement of Economic Performance and Social Progress, appointed by President Nicolas Sarkozy of France to consider these issues and chaired by Joseph Stiglitz, concluded that currently we do not have the data to produce a single number that can tell us convincingly whether we are sustainable (Stiglitz, Sen, and Fitoussi 2009). What we would really like to have is the ANS measure, but we are not yet able to construct this accurately because we do not have good quantitative measures of some aspects of wealth, nor do we have measures of the economic values of several important types of wealth. Prominent among the categories of wealth that we cannot measure or value fully are some types of natural capital. The commission suggested that we measure ANS as best we can and continue to improve our measures until we have good ones, and that in the meantime we supplement the ANS with some additional data that indicate the physical state of some of the more important environmental threats that cannot be captured by a wealth measure, such as the concentration of greenhouse gases in the atmosphere, the number of species close to extinction, and the acidity of the oceans.

The bottom line here is that we are not doing well in measuring the sustainability of our economic activities, and that while we do not yet have the data to do a great job, we can do a lot better than we are currently doing. The question of whether we are behaving sustainably is sufficiently important that we need to be working harder to find the answer.

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