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SUSTAINABILITY AND ITS MEASUREMENT

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**ABSTRACT**

I present a non-technical high-level review the concept of sustainability and the various approaches to quantifying it.

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## Sustainability and its Measurement

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**Abstract:** I present a non-technical high-level review the concept of sustainability and the various approaches to quantifying it.

**Key words:** Sustainability, GDP, NDP, adjusted net savings, genuine savings, green GDP, natural capital

JEL classification: Q 20, Q 30, Q 50, H 00

### **Overview**

In business schools there is a saying 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: these are almost entirely unmeasured, and often unmanaged too.

Economic measurement is never easy: economic systems are immensely complex. It might be helpful to begin by thinking about something more straightforward than managing an economy – driving a car. Whenever we drive, the car’s dashboard provides us with some basic data: how fast we are going, how hot the engine is, how fast it’s revving, and some warnings about possible problems via a range of warning lights. And of course there is the fuel gauge showing us how much longer we can drive. In modern cars this data is often supplemented by a satellite navigation system, telling us exactly where we are and how to get to our destination. The people who manage our economies would love to have the equivalent information about the economies they manage, but in general they don’t. They are far less well informed about their task than the average car driver about hers.

We do have something like a speedometer, the rate of growth of gross domestic product. We have data on unemployment and inflation, which are warning lights of a sort. We don’t have anything like a satellite navigation system: we often

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don't know exactly what is happening in the economy until a quarter or more after it has happened, because data are collected slowly.

Perhaps most striking, we don't have anything analogous to the fuel gauge, telling us how much longer we can carry on doing what we are doing. The analogue of the fuel gauge would be an indicator of sustainability, telling us how much longer our forms of economic organization can continue as is without spluttering to a halt.

None of the usual numbers – GDP, unemployment, inflation – tell us anything about the state of our natural capital. In fact they can be positively misleading.<sup>2</sup> 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. The extra spending raises GDP. So water shortages appear to be raising India's GDP, making India better off, and indeed they are in a macroeconomic sense raising economic activity. But more important is the fact that they are a threat to its growth: when it is no longer possible to find more water by drilling deeper, agricultural output will collapse and welfare will drop.

Here we are missing a warning sign – falling water table - and wrongly reading it as a contribution to growth.

### ***Alternatives to GDP***

What changes in our measures of economic performance would improve upon GDP and give an accurate signal about our environmental performance? A relatively simple move, at least conceptually, would be to move from gross domestic product GDP to net domestic product NDP. The difference is that the depreciation of capital is subtracted from GDP to calculate NDP. In the national accounts as they currently exist, the capital whose depreciation is subtracted is physical capital, the only type of capital that is measured currently. So subtracting the depreciation of physical capital will convert GDP to NDP, and this is really a better measure of what the economy is producing, what it is making available to its members. The reason

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<sup>2</sup> For a more general critique of GDP see Stiglitz Sen and Fitoussi 2010, and the pioneering work of Nordhaus and Tobin 1972.

we work with GDP rather than NDP is purely pragmatic: it is hard to measure depreciation of capital accurately.

From an environmental perspective the difference between GDP and NDP matters, 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: this country makes its living by extracting and selling oil. Oil is a form of natural capital, so they are running down their natural capital. Each year their stocks of oil are lower than they were the previous year, the decrease representing depreciation of their natural capital. The depreciation of this capital is the value of the oil that they sell, so that if we were to calculate their Net Domestic Product by subtracting depreciation of natural capital from GDP, this would more or less cancel out their income from the sale of oil, which is most of their income, leaving them poor.<sup>3</sup>

The conclusion here is that NDP is a better measure of output than GDP, particularly if we make the effort needed to measure and value changes in natural capital. It is an improvement on what we have today, but by no means the real answer to the question “What should we measure?”

Some people have tried to answer this question by moving away altogether from a money-based income measure and constructing something that tries to measure the well-being of members of a society more directly. The best known of these is the Human Development Index (HDI), developed and published by the United Nations Development Program (UNDP). The HDI is based on three sets of data relating to health, education and income, which UNDP sees as the key dimensions of welfare. These are life expectancy at birth, mean years of schooling and average income per capita. The UNDP takes data for these and combines them into a single number, the country’s score on the HDI. The HDI does not address

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<sup>3</sup> For an early recognition of this point see Repetto et al 1989 and Dasgupta and Heal 1979.

environmental issues, but could provide a model for non-monetary measures including environmental data, some of which have been developed recently.<sup>4</sup>

An intriguing variant on the conventional approaches is found in the small Himalayan kingdom of Bhutan, where economic and social performance is measured by the index of Gross National Happiness (GNH). The country's Buddhist culture influenced its decision to move towards a measure more spiritual than GDP, with its exclusive emphasis on material possessions. GNH tries to take into account performance on nine dimensions: Psychological Well-being, Time Use, Community Vitality, Culture, Health, Education, Environmental Diversity, Living Standard and Governance. Environmental diversity is intended to be a measure of the health of natural capital and ecosystems, and 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 non-work 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: how well is it in fact possible to measure these concepts, how do we combine the results of measurement into a single number and in particular whether this could be done in a country the size and complexity of the US.

To get some sense of the pictures given by these different measures of economic performance, figures 1, 2 and 3 show GDP per capita, the HDI and a quantity called Adjusted Net Savings – which we will explore below in connection with sustainability issues—for six countries, the U.S. and Germany, two leading industrial countries, China and India, the two preeminent emerging economies and

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<sup>4</sup> See for example the CIESIN index, CIESIN no date.

leaders in the BRIC group, and Botswana and Papua New Guinea, two small countries that are interesting examples.<sup>5</sup>

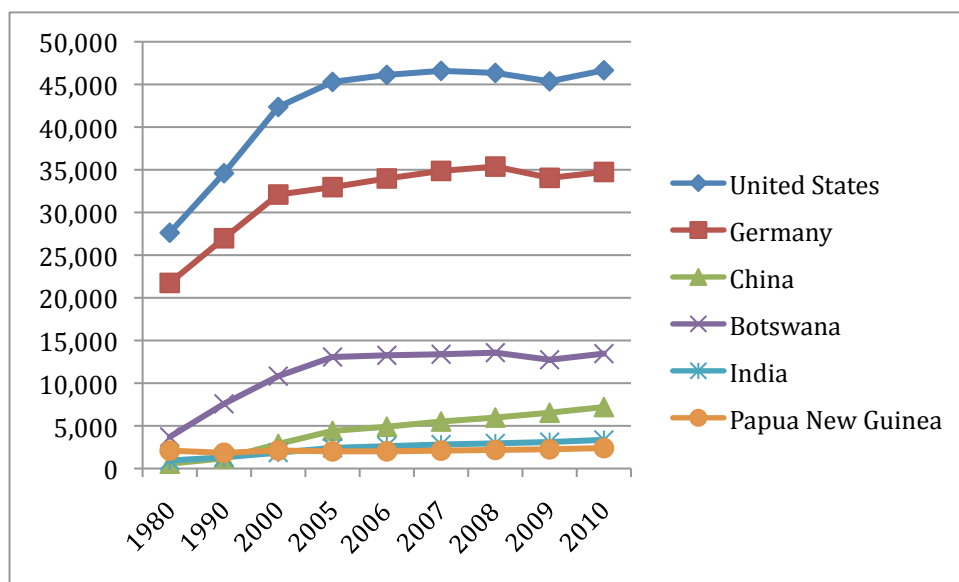


Figure 1: GDP per capita for selected countries, 1980 to 2010. Source: UNDP

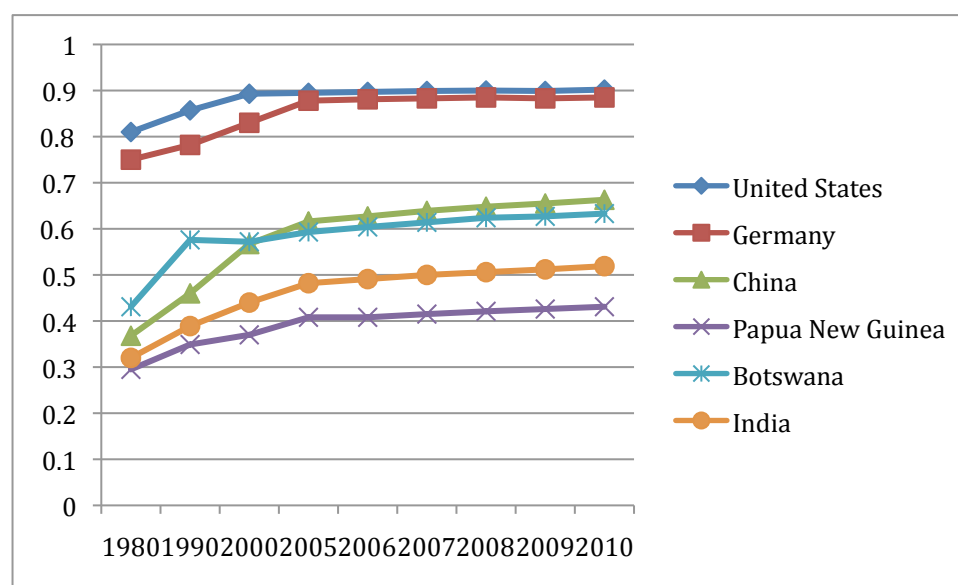


Figure 2: Human Development Index HDI for selected countries, 1980 to 2010. Source: UNDP

<sup>5</sup> All data in these figures is drawn from the web site of the United Nations Environment Program.

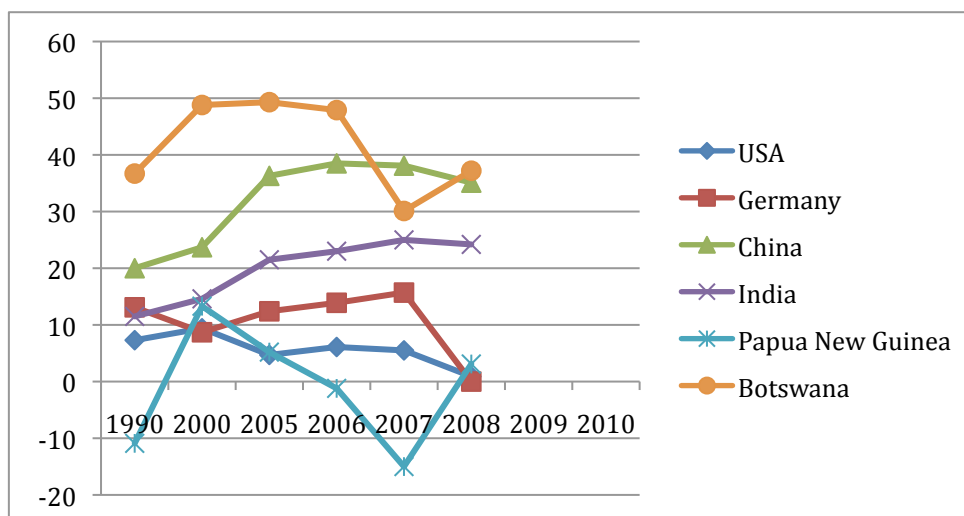


Figure 3: Adjusted Net Savings as % of Gross National Income, selected countries, 1990 to 2008. Source: UNDP

Figure 1 shows that for all these countries GDP per capita has risen over the last thirty years. However the implications of this for the wellbeing of the average citizen are far from unambiguous.<sup>6</sup> It also shows the US and Germany as being far richer than the rest, and shows very clearly that Botswana is much richer – in GDP terms at least – than China or India.

If we move to figure 2 and the HDI, although the measure we are using here 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 rich countries come at the top, though they are much closer than before. Now China ranks on a par with Botswana, and again India and Papua New Guinea are at the bottom.

Adjusted Net Savings (ANS), shown in figure 3, is one of the better measures of sustainability and is perhaps something of an analogy to the fuel gauge on a car. Now we see a completely different picture: Botswana dominates the top ranking, with China second. The US and Germany do not fare well. Being rich perhaps is not the same as being sustainable – a good entry to the issue of sustainability.

<sup>6</sup> See Stiglitz Sen and Fitoussi 2010.



## Sustainability

When it comes to human wellbeing there are two distinct questions that we might ask – firstly how well off are people now, and how this level is changing over time, and secondly whether current levels of wellbeing can be sustained over time. Will our successors be able to live as well as we do? GDP and its various refinements and the HDI (as in figures 1 and 2 above) are attempts to answer the first question. The second question leads into a discussion of sustainability, to some degree 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 is not new: it was addressed extensively in the 1970s literature on exhaustible resources, and indeed dates back to Malthus.<sup>7</sup>

### ***Some Examples***

Botswana, Namibia and Saudi Arabia are good countries to think about when trying to understand sustainability. Botswana and its neighbor Namibia are similar, with a long border in common: both arid or semi-arid 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 land-locked. 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

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<sup>7</sup> See Dasgupta and Heal 1974, 1979, Solow 1974, Stiglitz 1974, Hartwick 1977.

environment varies from aquatic where the river first reaches the desert, home of crocodiles and hippos and a range of fishing birds, to semi-arid scrubland on the fringes of the areas irrigated by the river. The Okavango Delta provides the basis for Botswana's immensely successful ecotourism industry: it's a natural asset that drives 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 the kinds of natural environments that support ecotourism, both are rich in minerals. Botswana has huge deposits of gem-quality diamonds. Namibia also has diamonds, though fewer than Botswana, but is in addition rich in uranium, lead, tin, zinc, silver and tungsten. The long Atlantic coast also gives it large fishing grounds.

Both countries are generating income by depleting natural capital – their diamonds, uranium, lead, fish etc. They are also generating ecotourist income from their unique biodiversity. They could be offsetting their depletion of natural capital by building up holdings of other forms of capital, or they could be letting their total stock of capital assets fall. As it happens, Botswana is doing the former and Namibia the latter. Botswana is a paragon of sustainability as figure 3 above shows: neighboring Namibia is not. Botswana is in fact 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.

The ultimate in unsustainability is Saudi Arabia. It is rich, certainly, but not sustainable – again we see that these are very different concepts. Saudi Arabia makes its living by selling its oil reserves, in effect selling off the family silver. Eventually – though 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. Its living standards are not sustainable in the long run.

### ***Sustainability: The Concept***

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. 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. And they are threatened by a changing climate.<sup>8</sup> They are also probably dependent 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.<sup>9</sup>

The Brundtland Report,<sup>10</sup> written for the United Nations by a committee chaired by the ex Prime Minister of Norway, Dr. Gro Harlem Brundtland, commented that "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Although vague, this definition has been adopted by many people. One point that this definition does make clear is that there is an intergenerational aspect to sustainability: we could live well now but ruin the Earth in the process and pass on to our successors a world greatly diminished – as the examples at the end of the previous paragraph suggest we may be doing. The Brundtland idea of sustainability enjoins us not to do this. In this respect, sustainability is a bit like estate planning. Most parents will want to leave their children the means to be comfortably off but will not want to bequeath so much to them as to seriously impair their own lifestyles. So one component of being sustainable is like global estate planning: we have to show an appropriate level of concern for our successors. This idea of responsibility to later generations is often interpreted as meaning that we should

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<sup>8</sup> See Schlenker Fisher and Hanemann 2005

<sup>9</sup> For analytical discussions of the concept of sustainability, see Heal 1998 and Neumayer 2010.

<sup>10</sup> Formally the Report of the World Commission on Environment and Development, 1987.

leave them enough assets to be as well off as we are, and this goal is built into the idea of ANS shown in figure 3, and considered in detail below. ANS can tell us whether we are leaving enough for future generations to be as well off as we are.

### **Trading Natural for Physical Human and Intellectual Capital**

There is another dimension of sustainability, omitted by the Brundtland definition, that has to do with the environment – the examples of unsustainable behavior mentioned above concerned greenhouse gases and agriculture, both involving environmental impacts. The natural environment, natural capital, is of immense value to human societies. We depend on it in many ways, and there are services that it provides that we probably could not replace.<sup>11</sup> 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 than we have, less than we inherited from our predecessors. It is this environmental damage and depletion of natural capital that may be making our activities unsustainable. We are leaving our successors 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. Perhaps this is condemning them to an impoverished lifestyle.

To be fair to ourselves, as a possible offset against this we are leaving them more than we inherited in the way of built capital: more freeways, airports, buildings, and infrastructure. And we are also leaving them more intellectual capital: our research and development programs are developing cures for diseases, new products, 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 in compensation for the depleted environment that we leave them.<sup>12</sup>

Will this compensation be adequate? Can we compensate for a depleted natural environment by more of the fruits of human labor and ingenuity? So far we

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<sup>11</sup> See Daily 1997 and Heal 2000.

<sup>12</sup> For a very clear documentation of these trends in the composition of capital stocks see World Bank 2006 and World Bank 2010.

certainly have: we are by general consent far better off than our predecessors a century ago, and in the interim what has happened is that we have built up our intellectual and physical capital massively, while running down our natural capital. We have lost forests, rangelands, and quite a number of species, but 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 to date we seem to 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? Do we want to continue trading natural environments and endangered species for better technology and infrastructure? That's the nub of the sustainability issue.<sup>13</sup>

It seems likely that matters are changing and we won't in fact be able to compensate in the future for the loss of natural 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, will lead to changes 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 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

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<sup>13</sup> It's 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 et al 1998 and LeKama and Schubert 2004.

populations of large fish in the sea – the ones we eat – are claimed to be down to about 10% of what they were only half a century ago.<sup>14</sup>

The bottom line here, then, is that we are depleting our natural capital faster than ever before, and have already depleted it to a great 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 tradeoffs will continue to work, that we can compensate for the loss of natural capital as we have in the past by more and more intellectual and physical capital.

### **Case Studies**

It is interesting to look in detail at this issue of compensating for the loss of natural capital by the buildup of other forms of capital in some specific cases. A good example is Saudi Arabia. Let's look at some numbers to get a rough idea of the magnitudes involved. Saudi Arabia produces roughly ten million barrels of oil per day, and has a population of about twenty five million. At its peak oil was selling for about \$130 per barrel, though this is much higher than the average price for the last few years, which is below \$100. Anyway, at the high price of \$130 per barrel, Saudi annual oil revenues amount to just under \$19,000 per head. That is to say, if the total oil revenues were divided equally between all Saudis, then each would receive about \$19,000 per year. A family of four would have just under \$80,000. Not super-rich, 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 stop short. It is unsustainable. 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

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<sup>14</sup> There is some dispute about the accuracy of this claim: see Myers and Worm (2003) and Sibert et al. (2006).

income, then Saudi Arabia would be running its economy sustainably: if less than that amount is invested then it is being run unsustainably. Alternatively, income could be invested in productive assets such as factories in Saudi Arabia and in the education of its people. This too could generate a source of income that could replace oil revenues in due course.<sup>15</sup>

In contrast there are oil countries or regions that are trying to run their economies sustainably. Two good examples are Norway and Alaska, with the Norwegian State Petroleum Fund and the Alaska Permanent Fund. These are both funds set up to take revenues from the sale of oil and invest these to provide a long-run income source that will continue even after the oil reserves are depleted. In the case of the Norwegian State Fund, revenues for investment come from the government's 80% 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 now has accumulated about \$28 billion. It pays an annual dividend to all Alaska residents, averaging over \$1000 per year per head and peaking at \$1800. 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 this 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 build up of these offsets to some degree the rundown of the natural capital assets. If well-managed this could keep the total

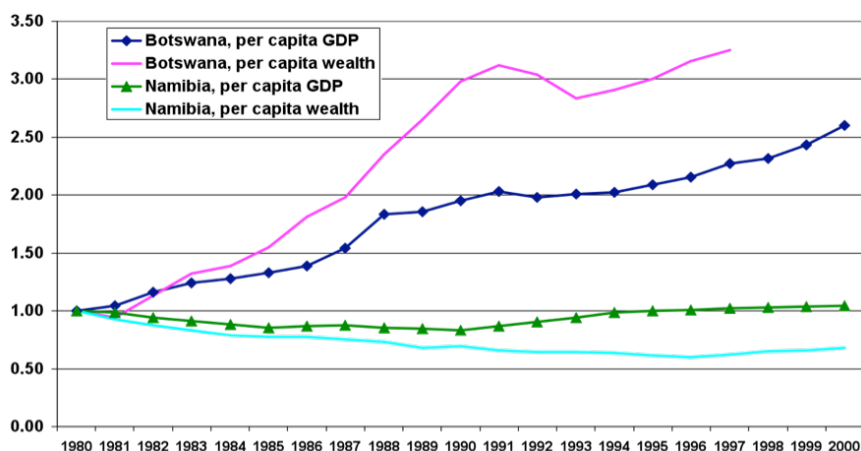
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<sup>15</sup> For more discussion of these issues see Heal 2007.

value of the country's assets constant. Saudi Arabia is clearly not doing this: Alaska and Norway may be.

The Government of Botswana has deliberately sought to invest a significant part of the revenues from diamond mining in physical and human capital.<sup>16</sup> Both wealth per person and income per person have roughly tripled in Botswana in the last twenty years, whereas 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 rule.<sup>17</sup> Lacking any explicit policy of using revenues from natural capital to build up other forms of capital, Namibia has seen falls in both its total capital stock, the total value of its assets, and its per capital income. Figure 4 shows this contrast.

### Index of real, per capita GDP and wealth in Botswana and Namibia, 1980 - 2000



Per capita wealth in 1980 (in US\$):

Botswana: \$ 5,562

Namibia: \$10,414

<sup>16</sup> See Lange 2004 and Lange and Wright 2004.

<sup>17</sup> See Hartwick 1977.



Figure 4: Source -

### **Tradeoffs Again**

What does this tell us about sustainability? It says that in the case of mineral resources, basing an economy on running down natural capital need not imply that income levels are unsustainable. You can compensate for the depletion of this type of natural capital by investing in other forms of capital, keeping your balance sheet intact and replacing one asset by another. The big question that this analysis raises is – is this also true for the depletion of forms of natural capital other than mineral resources? Can we expect to compensate for the loss of aspects of the climate system, or of the hydrological cycle, or of 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 allow 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 real issue here is the extent to which the services of capital constructed by humans can replace the services from living natural capital. Can we make substitutes for what we get from nature? In the limit the answer has to be no. We need oxygen, it's what powers our bodies. Oxygen is produced by photosynthesis, carried out by plants and by photosynthetic algae in the oceans. 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 world-wide carbon cycle, and on the actions of agricultural pests that attack food crops and their natural predators, such as birds and bats, that keep them under control.

We cannot replace all aspects of natural capital by physical or financial or intellectual capital. Mineral resources are just wealth: they provide their owners no other services than the wealth that they generate in the market. So we can compensate for their depletion by building up our wealth, along the lines of Alaska and Norway and Botswana. But forests and coral reefs and ecosystems in general

are more than just wealth and can't be fully replaced by financial assets or physical capital. This is what New York City decided when it chose to conserve the Catskill Watershed, and it's what the Chinese government decided 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.<sup>18</sup> The real issue here is 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 wellbeing, an issue modeled in a preliminary way in Heal (2010).

So sustainability requires that we maintain some of our natural capital intact, as it provides services that matter to us and that we can't replace, but there are other parts of natural capital that we can safely deplete as we can replace them with money or other assets that 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, in that we can replace it. Ironically, from the way markets are working at the moment you would think that it was exactly the opposite: mineral resources, and oil in particular, are valued very highly, and biodiversity and forests almost not at all.

### ***Sustainability – weak or strong?***

Sustainability comes in two varieties, weak and strong.<sup>19</sup> So far we'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 aren't compromising the ability of future generations to meet their needs, 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

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<sup>18</sup> For more details see Heal 2000.

<sup>19</sup> This distinction is discussed in detail by Neumayer 2010

stewardship of and responsibility towards the natural world and the other species who share it with us.

As a consequence, not everyone is convinced that this is what we should mean by sustainability: there are environmentalists who feel 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 and not just maintaining our own living standards, which they see as a narrow-minded and parochial goal. They see us as having responsibilities 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. Ultimately the choice between these two concepts 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 in so far 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 Endangered Species Act of the United States specifically seeks to save species from extinction even if there is no economic merit to doing so: it reflects the belief that species have a right to exist independently of their value to us, a position taken by an increasing number of people who feel that this is an issue on which they have to take a moral stance.<sup>20</sup> Personally I sympathize with them, agreeing that we do not have the right to condemn other species to oblivion. I also feel that it's economically unwise to do so, so that to me the two arguments lead in the same direction. Economists have studied both concepts of sustainability, and have called maintaining animate natural capital intact "strong sustainability" and maintaining human living standards "weak sustainability."

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<sup>20</sup> See Goble 2006 and Callicott 2006 for a development of this point.

Obviously the world is not currently sustainable in the strong or ethical sense: this requires maintaining animate natural capital intact, which in turn requires not driving other species to extinction. 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. We have spoken of Saudi Arabia, which is certainly not, and of Botswana, which is: there are many countries in between.

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 is small enough, the two concepts are not that different, whereas if it is large they are different and maintaining welfare levels does not require maintaining species.

### ***Measuring Sustainability***

We would like to be able to measure how sustainable or unsustainable our policies and institutions are, as the issues at stake are important and need to be the focus of our policy-making. Recall the adage “What gets measured, gets managed.” We need an equivalent to a car’s fuel gauge.

There is unfortunately no way in which GDP will indicate whether an income level or lifestyle is sustainable. For that we need to look at something quite different, at how total wealth is evolving, where by total wealth we mean the total value of all of capital stocks – natural capital, physical capital, intellectual capital and any other forms of capital that are relevant. Botswana has invested the rents from diamond mining in new forms of capital that replace the natural capital it is depleting, its wealth has grown over time, and as a result its living standards are sustainable. They are hedged against the expiry of its diamond mining operations. Likewise Alaska and Norway are partly hedged against the expiry of their oil reserves.

We think of income as the return on wealth or on accumulated assets; it’s the flow of payments or services from our wealth. John Hicks back in the 1930s 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 problem here that we need to look at carefully. I noted above that there are some aspects of natural capital that we probably cannot replace, particularly the animate aspects of it such as species and rainforests. If this is true, in what sense can we be sure that 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 will come back to this point.

When we talk about wealth, the total value of the stock of capital of all sorts, 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, though 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 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 being a good example. It is both an important component of natural capital and one in which there is typically no market and for which there are no

prices. In a case like this we need to calculate shadow prices, reflecting the value of the resources concerned to society – which is in fact exactly what price 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.<sup>21</sup>

It's important to understand the effect of scarcity on the price or shadow price of an essential form of natural capital. If some form of animate natural capital is truly essential to us and it is becoming very scarce, then its shadow price will rise sharply. This is the possible resolution of the difficulty noted above, that constancy of the value of total capital could mask a decline in important types of natural capital that are essential to our continuing wellbeing. Important goods, when scarce, become very expensive. If one unit of this capital has a huge shadow price – say one billion dollars – then if we lose one unit, to keep the total value of wealth constant we would need to compensate by one billion dollars of built or intellectual capital. And if the essential natural capital became 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 will indicate non-sustainability.

We have already encountered in figure 3 above a widely-used measure of sustainability that attempts to measure the change in a nation's total wealth, Adjusted Net Savings. Developed by the World Bank (see World Bank 2006 and 2010 and Hamilton and Hartwick 2005), Adjusted Net Savings 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, at least in the sense of weak sustainability.<sup>22</sup>

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<sup>21</sup> For a more extensive discussion of the valuation of natural capital and the services that it provides, see National Research Council 2005.

<sup>22</sup> There is some complex theory behind this statement. See for example Heal and Kristrom 2008, Hamilton and Hartwick 2005 and Arrow Dasgupta and Maler 2003.

We get ANS by starting with a conventional measure of net investment in plant and equipment, that is investment net of depreciation. Then we add to this investment in human capital through education and in intellectual capital through R&D, and then subtract the depreciation or degradation of natural capital. The World Bank produces figures for this number for each country, which is where the data I have presented originated, though I actually downloaded them from the web site of the United Nations Development Program (UNDP).

The following figure, figure 5, shows this process of calculating ANS: it is taken from Arrow et al. 2004. It shows that we start with domestic net investment (first column of numbers), then add to this to allow for education (investment in human capital), then subtract to allow for various forms of environmental damage that represent depreciation of natural capital. Finally we adjust for population growth, giving the rate of change of total capital per person. The final column shows ANS per capita, growth of total capital per person, for the various countries or regions. These adjustments clearly make a massive difference: for example, China's net domestic investment is 30.06% of its GDP, whereas after all adjustments the number is 7.77% - still positive, meaning that accumulation of non-environmental capital is more than compensating for the depletion of natural capital. These calculations are unfortunately very rough, and certainly overestimate ANS, because we have no good data on many aspects of environmental degradation and loss of natural capital.<sup>23</sup>

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<sup>23</sup> Probably the most sophisticated calculations of this type are in Arrow, Dasgupta, Goulder, Mumford and Oleson 2010.

Country	Domestic Net Investment	Education Expenditure	Damage from CO2 emissions	Energy depletion	Mineral depletion	Net forest depletion	ANS	ANS per capita
Bangladesh	7.89	1.53	0.25	0.61	0.00	1.41	7.14	0.30
India	11.74	3.29	1.17	2.89	0.46	1.05	9.47	0.54
Pakistan	10.92	2.02	0.75	2.60	0.00	0.84	8.75	0.59
China	30.06	1.96	2.48	6.11	0.50	0.22	22.72	7.77
Sub-Saharan Africa	3.49	4.78	0.81	7.31	1.71	0.52	-2.09	-2.58
Middle East & North Africa	14.72	4.70	0.80	25.54	0.12	0.06	-7.09	-3.82
United Kingdom	3.70	5.21	0.32	1.20	0.00	0.00	7.38	2.29
United States	5.73	5.62	0.42	1.95	0.05	0.00	8.94	0.75

Figure 5: the calculation of ANS. All figures expressed as a % of GDP.

Figure 6 shows more data on ANS, and references the examples we discussed earlier: it shows the movement of ANS as a percent 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. We know why. Namibia, almost a twin of Botswana in many ways, is much less virtuous in building up its capital stocks, though its ANS is still commendably positive. And 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 talk of the constancy of total wealth as indicating sustainability, then we are talking about the sustainability of living standards, weak sustainability, which was the focus of the Brundtland



definition. That definition spoke of the ability of the present generation to meet its needs without compromising the ability of future generations to do likewise. We are not measuring whether living natural capital is being maintained at a reasonable level.

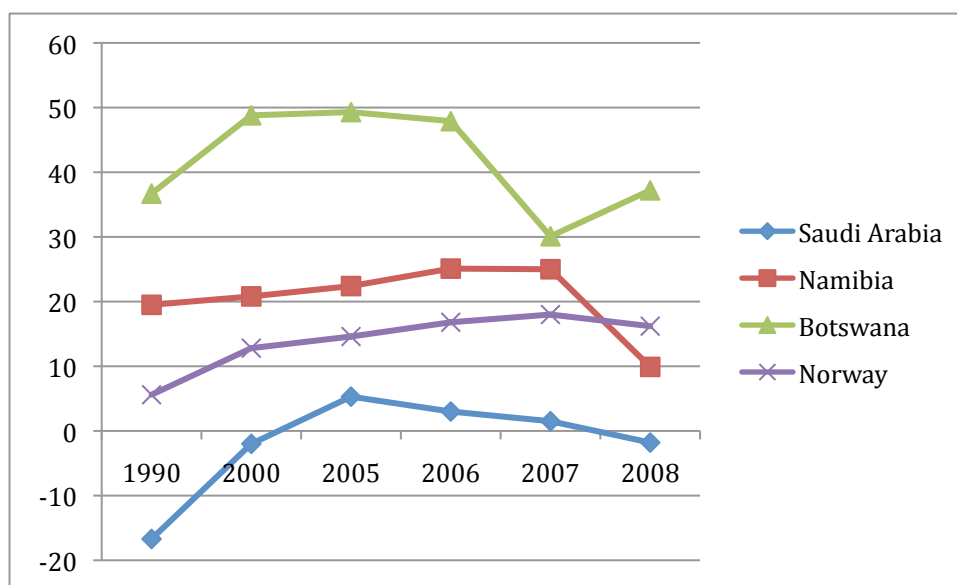


Figure 6: ANS for Botswana, Namibia, Norway and Saudi Arabia from 1990 to 2008.  
Source: UNDP

## Conclusions

Where does this leave us in our overall assessment of sustainability and its measurement? The concept matters: we need to know whether we are compromising the abilities of future generations to live as we live. We also need to know whether we are sentencing a large fraction of life on earth to death to the power two, to extinction and complete obliteration. Both of these issues matter and on the surface reflect somewhat different interpretations of sustainability. But some researchers, particularly in biology and ecology, claim that 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 they are saying that there is limited substitutability between some type of natural capital and other forms of capital.<sup>24</sup>

And where are we when it comes to measuring sustainability, and judging whether we are managing our affairs in a sustainable fashion? In the commission appointed by President Sarkozy to consider these issues,<sup>25</sup> chaired by Joe Stiglitz, we concluded that currently we don't have the data to produce a single number that tells us convincingly whether we are sustainable. The Adjusted Net Savings measure is what we would really like, but we don't have good quantitative measures of some aspects of wealth, and nor do we have measures of the economic values of several important types of wealth, so we can't yet construct an accurate measure of ANS. Prominent in the categories that we can't measure or value fully are some types of natural capital. The commission suggested that we measure ANS as well as we can, and continue to improve our measures till we have good ones, but in the meantime supplement this with a small number of additional numbers showing the physical state of some of the more important environmental threats that cannot be captured by a wealth measure, examples being the concentration of greenhouse gases in the atmosphere, the number of species close to extinction and the acidity of the oceans.

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<sup>24</sup> For a discussion see Ehrlich and Goulder 2007.

<sup>25</sup> Stiglitz Sen and Fitoussi 2009.

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