Nature and the Economy*

by

Partha Dasgupta, FBA FRS
University of Cambridge

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The author is the Frank Ramsey Professor of Economics at the University of Cambridge and Fellow of St John's College, Cambridge.

Summary

In this lecture I first offer what one could call the World Bank view of the recent macroeconomic history of a number of countries in the poor and rich worlds. The second thing I do is to demonstrate how very different macroeconomic history begins to look if Nature is included as a capital asset in production activities. The tentative conclusions I draw from the evidence are:

1. High population growth in the world's poorest regions (South Asia and sub-Saharan Africa) has been an obstacle to the achievement of sustainable economic development there. We have good reasons for believing that people in those regions are on average less wealthy now than they were 35 years ago.

Relatedly,

2. When population growth is taken into account, the accumulation of manufactured capital, knowledge, and human capital (health and education) has not compensated for the degradation of natural capital in South Asia and sub-Saharan Africa and, in all probability, even in the UK and US.

3. China is probably an exception to (1) and (2).

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Motivation

Ecologists and economists have much to say to each other, yet they rarely converse. There are exceptions of course - the invitation to address your conference is an instance of this. I have found, though, that ecologists typically don't read economics even when they come to deploy economic reasoning, and economists blissfully neglect ecology when studying the economic progress of communities and nations.

In order to engage you in economics and show you that ecological truths can be introduced into economic reasoning in a seamless way, I shall first offer you what one could call the World Bank view of recent macroeconomic history in a number of countries in the poor and rich worlds. No doubt many of you will be familar with the statistics (Table 1); nevertheless it will be useful to look at them, because the second thing I want to do is to show you how very different macroeconomic history begins to look if you include Nature as a capital asset in production activities (Table 2).

The underlying motivations behind my lecture are thus twofold: First, I want to argue that it's high time growth economists, demographers, governments, and international agencies took Nature seriously. Second, I want to show you that progress has been made in recent years, among small groups of ecologists and economists, in developing the correct way to study the progress of economies - whether the study is for descriptive or for prescriptive purposes.

1 Official Macroeconomic History

In order to talk of economic progress or failure, we need a measuring rod. The one most commonly used today is *gross domestic product* per person - *GDP* per capita. Economists may have invented the concept and may have also warned against its many limitations; but, like it or not, the term is so ingrained in public consciousness, that if someone exclaims, "Economic growth!", we don't need to ask, "Growth in what?" - we know they mean growth in *real* GDP per capita; which is growth in GDP per capita, corrected for inflation or deflation.

A country's GDP is the value of all the final goods that are produced by its residents in a given year. It is a measure of an economy's total output. But when a commodity is produced and sold, the price paid for the purchase finds its way into someone's pocket. So, GDP can be measured also by adding up everyone's incomes - wages, salaries, interests, profits, and government income. GDP and national income are therefore two sides of the same coin.

Although GDP is often said to measure wealth, it doesn't do so. GDP is a *flow* (dollars per year, say), whereas wealth is a *stock* (dollars - period). As the concept of GDP was developed originally for market economies, the values imputed to the goods were market prices. But by a clever construction of notional prices (called "shadow prices"; see below), economists have adapted GDP even for economies where large volumes of transactions are undertaken in non-market institutions.

Adjusting for differences in the cost of living across the world, global income per head today is about $8,000 a year. But for most of humanity's past, people have been abysmally poor. The economic

statistician Angus Maddison has estimated from the very fragmentary evidence that exists, that, at the beginning of our Common Era (CE 0) the per capita income of the world was about $515 a year in today's prices (Maddison 2001). If Maddison's estimate is even approximately correct, it means that the average person 2000 years ago enjoyed not much more than a dollar a day, a figure deemed by the World Bank as the line below which a person is in extreme poverty. Maddison has also suggested that the distribution of income 2000 years ago was remarkably equal: almost everyone, everywhere was very poor. The figures he has constructed tell us furthermore that average world income and the regional distribution of income per head were pretty much the same in CE 1000 as they had been a thousand years earlier. It would appear that regional disparities became significant only from the beginning of the 19th century: income per head in Western Europe had by then become three times that in Africa. But world income per head was still only $755 a year in todays' prices, meaning that it had increased by less than 50% over a 1800 year period; amounting to an annual growth rate of under 0.02%. The figure is extremely low by contemporary standards: the annual growth rate of income per head has been 2% a year over the past four decades. (A useful formula to remember is that, if a numerical entity - say real GDP per person - grows (or declines) at the annual rate of g%, that entity doubles (or halves) approximately every 70/g years. Examples: GDP per capita would double every 35 years if it were to grow at an annual rate of 2%; and halve every 140 years if it declined at an annual rate of 0.5%.)

Large regional disparities in income are also less than 200 years old. The ratio of the average incomes in the US and Africa has risen from three in the beginning of the 19th century to more than 20 today - about $38,000 compared to $1,850 per year. Real GDP per capita in the US has grown 30 times in size in 200 years, implying that the average annual growth rate of income per person there has been about 1.7%. In sad contrast, income per capita in Ethiopia is about the same today as it was 200 year ago (a little over $700 a year today).

If you were to line up countries according to GDP per capita today, you would find two clusters: one *poor*, the other *rich*. There are middle-income nations spread thinly between the extremes (China, Brazil, Venezuela, and Argentina are prominent examples), but a large cluster of countries (in sub-Saharan Africa, the Indian sub-continent, South East Asia, Melanesia, and Central America) - with a total population of 2.3 billion - produces an average $2,100 a year per head, while another, smaller, cluster (Europe, North America, Australia, and Japan) - with a total population of a bit under 1 billion - enjoys an average annual income of $30,000 (Table 1). The world would appear to be polarized. Moreover, with the exception of India, there is little sign that the poor world will catch up with the rich world in the foreseeable future. During the past four decades, real per capita GDP has grown at an average annual rate of 2.4% in rich countries, whereas it has grown at 1.8% in poor countries (Table 1). Worse, within the poor world sub-Saharan Africa has experienced a small decline in real GDP per capita during the past four decades.

In contrast to poor countries, agricultural output is a small fraction of national income in the rich

world. The share of agriculture in GDP is about 25% in the poor world; less than 5% in rich countries. Less than 10% of the population in rich countries live in rural areas. In contrast, more than 70% of people in poor countries live in villages (Table 1); which gives rise to the thought that people in poor countries mostly work in economies that draw their production inputs directly from Nature - they are "biomass based" economies. Ecology is of direct concern to the world's poor, in a way it isn't to the world's rich.

Recently the United Nations Development Programme (UNDP) has sought to extend the basis on which the standard of living is measured. It has done so by constructing a numerical index that combines GDP per capita, life expectancy at birth, and literacy. UNDP has christened it the Human Development Index (HDI). Again, leaving aside a few exceptions, HDI has been found to be low in poor countries, high in rich countries (Table 1).

1.1 Proximate causes behind differences between the rich and poor worlds

What enables people in rich world to be so much richer than people in the poor world? Several features suggest themselves:

People in rich countries have better equipment to work with (electric drills are more powerful than pick axes; tractors are superior to ploughs; and modern medicine is vastly more effective than traditional cures). So, one argument goes that the accumulation of physical capital (more accurately, *manufactured* capital) in the rich world has been a significant contributor to the high standard of living people enjoy there.

Others have noted that people in rich countries are far better educated, implying that they are able to make use of ideas to produce goods that are out of reach for people in countries where large numbers are illiterate. A crude index of education is the proportion of adults (people aged 15 and above) who are literate, the figure for which today is over 95% in the rich world, but only 58% in the poor world (Table 1). Gender inequalities are considerably greater in the poor than in the rich world. The proportion of adult women who are literate in poor countries is 48%, whereas in the rich world the corresponding proportion is pretty much the same as that for men, namely, over 95% (Table 1). Allied to education is health. Life expectancy at birth in rich countries is now 78 years, whereas it is about 58 years in poor countries. Some 120 children among every 1000 of those under 5 years of age die each year in the poor world; the corresponding figure for rich countries is 7 (Table 1). Relatedly, clean water and good hygiene have reduced morbidity in rich countries greatly. About a quarter of the population in the poor world suffer from undernourishment, whereas the corresponding figure in rich countries is negligible. As undernutrition and vulnerability to infections reinforce each other, poor nourishment and morbidity go together. There is evidence that undernourishment in early childhood affects the development of cognitive faculties. Taken together, the average person in the rich world is capable of supplying work of far higher quality and for many more years than his counterpart in a poor country. Education and health go by the name, *human capital*. A literature pioneered by Schultz (1974) and Becker (1983) reveals that

the accumulation of human capital has been a significant factor behind the high standard of living people in the rich world enjoy today.

Many economists, however, regard the production of new ideas as the prime factor behind economic progress. They say that rich countries have become rich because people there have been successful in producing ideas not only for new products (printing press, steam engine, electricity, chemical products, the electronic computer), but also for cheaper ways of producing old products (transportation, mining). Of course, education and advances in science and technology combine as an economic force. Primary and secondary education alone can't take a society that far today. A country where tertiary education is low would not have a population capable of working with the most advanced technology. Nor are scientific and technological advances capable of being achieved today by people with no advanced education.

Related to this is an issue that has proved to be far more contentious than it should have been: population growth. Even unaided intuition suggests that if numbers grow quickly, the rate at which capital assets must increase would need to be high in order to maintain living standards. If the desire to accumulate physical and human capital is the same in two countries and if rising numbers don't reduce the cost of accumulating that capital, the country where population grows at a slower rate can be expected to enjoy a higher living standard in the long run. Since the mid 1960s, population in what is today the poor world has grown at an average annual rate of 2.4%, while the corresponding figure in today's rich world has been 0.8% (Table 1). This is a big difference. Statistical demographers now at last agree that, controlling for other factors, countries where population increase has been large in recent decades have experienced slow growth in real GDP per capita. High population growth in today's poor countries has also put enormous pressure on their ecology, creating further problems for rural people (Dasgupta 2001).

A country's population growth is affected not just by net reproduction, but by net immigration and the age distribution too. In order to isolate net reproduction, it is common practice to work with the *fertility rate* (more accurately, the *total fertility rate* or *TFR*), which is the number of live births a woman expects to deliver over her life. Suppose parents desire to have a certain number of surviving children. Then the fertility rate should decline once the mortality rate among children under 5 starts to decline. Demographers have puzzled why reductions in fertility rates in today's poor world have been slower than they had expected. The first known decline in fertility rates in north-western Europe (England and France especially) occured in the 17th century, when it fell from about 7 to 4. The fertility rate in the rich world today is 1.8 (below 2.1, the figure at which population would stabilise in the long run), whereas it is 3.7 in the poor world (Table 1). Despite a significant decline in child mortality rates, the TFR in a number of countries in sub-Saharan Africa continues to be between 6-8. We should ask whether there have been countervailing forces at work to keep fertility rates high in that continent. We should ask too whether the resulting population growth has been a factor in its terrible economic performance over the

past four decades. We will study the question in greater detail later, but one implication of high fertility rates for women's conditions follows at once:

In sub-Saharan Africa, extended breastfeeding has been a traditional practice for controlling pregnancies. Among the !Kun San nomads of the Kalahari desert, children have been known to be breast-fed until they are four years old. Even if we were to ignore such extreme cases, successful reproduction in Africa would involve 2 years of pregnancy and breastfeeding. This means that in societies where female life expectancy at birth is greater than 45 years and the fertility rate is 8, girls can expect to spend more than half their fecund life (say, 15-45) in pregnancy or nursing; and we have not allowed for unsuccessful pregnancies. Under these circumstances rural women in poor countries are unable to seek employment outside subsistence agriculture.

No economist has ever claimed that there is a single driving force behind economic growth. All would appear to agree that the accumulation of manufactured capital, human capital, and the production, diffusion and use of new scientific and technological ideas go together, each contributing positively to the contributions of the others. In the contemporary world, an accumulation of, say, manufactured capital goods raises real GDP, other things being equal. This enables societies to set aside more of their incomes for education and health, triggering a reduction in both fertility and child mortality. Education increases GDP further, other things being equal, while reduced fertility and child mortality typically lower population growth; which, taken together enable societies to set aside more of their incomes for the production of new ideas. This raises the productivity of manufactured capital; which in turn brings forth further accumulation of manufactured capital; and so on, in a virtuous cycle of prosperity. The flip side of this is, of course, a vicious cycle of poverty. The polarization that separates the rich and poor worlds today is a manifestation of those two movements. Economists use the terms *virtuous* and *vicious* cycles to characterise polarization (a few of us refer to vicious cycles as *poverty traps*); mathematicians say instead that the poor and rich worlds are in two different *basins of attraction.*

It is possible to discover the relative importance of the various factors responsible for economic growth. No doubt the answer is different in different places and in different periods of history; but five decades ago, Robert Solow showed us how to investigate the question, by devising a way to decompose recorded changes in an economy's real GDP into their measurable sources (Solow 1957). Suppose that over an interval of time a country's real GDP has increased. Solow, and subsequently others, showed how to attribute that growth to increases in labour force participation (population growth; increases in women's employment in paid labour), the accumulation of human skills and manufactured capital, improvements in the quality of machinery and equipment, and so on. Now suppose that when we have added up all the contributions made by these factors of production, we find that the sum falls short of real GDP growth. We are entitled then to interpret that shortfall as an increase in the overall productivity of the economy's capital assets; by which we mean that more output can be produced now than earlier even if the amounts of such factors of production as machines and equipment and skills had remained the

same. This is a formal way of acknowledging that there has been a general rise in the efficiency with which goods are produced. Economists call that rise, growth in *total factor productivity*.

How does that latter growth come about? It comes about when people acquire knowledge and make use of it, or when people make better use of what they already know. Which is why economists often refer to growth in total factor productivity as *technological progress*. But there are other changes in an economy that could leave an imprint on total factor productivity, such as improvements in the workings of institutions. Growth in total factor productivity may be an ungainly way to convey an idea, but it reflects the unexplained bit of real GDP growth pretty well. In the economics literature the name has come to stay.

Since the Second World War, growth in total factor productivity in the rich world has been considerable. It has been estimated, for example, that during 1970-2000 the average annual rate of growth of total factor productivity in the United Kingdom (UK) was 0.7%. Economists have estimated that, in contrast, total factor productivity *declined* slightly in a number of countries in sub-Saharan Africa during that same period.

What do these figures mean? Take the case of the UK. The country's real GDP grew at an average annual rate of 2.4%, which means about 29% of that growth (i.e., 0.7/2.4) could be attributed to increases in total factor productivity. At 2.4% growth rate, real GDP in year 2000 was twice the real GDP in 1970. Nearly a third of that increase can be attributed to growth in total factor productivity. In contrast, the economies in sub-Saharan Africa where total factor productivity declined during that period became less efficient in their use of such factors of production as machines and equipment, skills and labour hours. It's hard to believe that people in those countries systematically forgot technical knowledge they had known in the past. So the decline in factor productivity there must have been due to a deterioration in local institutions, precipitated by civil wars and bad governance.

These statistics raise a puzzle. Today's poor countries lie mainly in the tropics, whereas the rich countries are mostly in temperate zones. No doubt the tropics are a breeding ground for germs, but they also harbour vast quantities of natural resources (timber; minerals; and conditions suitable for the production of spices, fibres, coffee, and tea). During the past several centuries, the countries that are rich today have been importing those very resources and products to fuel their factories and mills, and to make their meals enjoyable. They accumulated machines, human capital, and also produced scientific and technological knowledge. Why didn't the poor world take advantage of their resource endowments to enrich themselves in the same way?

Colonization is a possible answer. Historians have shown that, from the 16th century, European powers have extracted natural resources from the colonies - including cheap (read, slave) labour - but have mostly invested the proceeds domestically. Of course, one should ask why it is that the Europeans managed to colonize the tropics; why colonization didn't take place the other way round. Diamond (1997) has scanned 11,000 years of settled communities to conclude that Eurasia enjoys geographical

advantages over the rest of the world that were crucial to the rise of economic activity there. That said, many of the most prominent of those ex-colonies have been politically independent for decades now. During that time real income per head in the rich world has increased over and over again. With the exception of a few striking examples in South and South-East Asia, though, most of the ex-colonies have either remained poor or become poorer still. Why?

1.2 Institutions

North and Thomas (1973) and Landes (1998), among other economic historians, have argued that the rich world is rich today because, over the centuries, it has devised institutions that have enabled people to improve their material conditions of life. This is a deeper explanation. It says that people in rich countries work with superior technologies, are healthier, live longer, are better educated, and produce many more productive ideas, *because* they have been able to get on with their lives in societies whose institutions permit - even encourage - the economy-wide accumulation of such factors of production as machines, transport facilities, health, skills, ideas, and the fruits of those ideas. The accumulation of productive capital assets is only a proximate cause of prosperity, the real cause is progressive institutions.

One can peel away the conceptual onion some more and ask how and why past people in today's rich countries were able to fashion their institutions in ways that enabled those proximate causes of prosperity to explode there. One can even ask whether institutions did it, or whether it was the enlightened policies of the rulers that were responsible for the explosion. But then, policies aren't plucked from air, they emerge from consultations and deliberations within institutions. Nor is it likely that a policy designed to bring prosperity to a country will actually work unless the institutions there are capable of implementing it.

These dilemmas are of enormous importance for today's poor countries. What institutions should they adopt and what policies should their governments be encouraged to follow? There is little point in embarking on grandious projects (steel mills, petrochemical plants, land reform, public health programmes, free education) unless a country's institutions have the necessary checks and balances to limit corruption and wastage. This brings us back to our earlier question: how did those institutions that promoted economic growth in today's rich countries get established and flourish? Despite the attention the question has received from the world's most outstanding economic historians, the matter remains unsettled. There are also theoretical difficulties in answering the question (Dasgupta 2006). In view of the difficulties, it is safest to regard institutions as the explanatory factor when we seek to understand why the rich and poor worlds differ so much in terms of the standard of living.

The effectiveness of an institution depends on the rules governing it and on whether its members obey the rules. The codes of conduct in the civil service of every country include honesty, but governments differ enormously as to its practice. Social scientists have constructed indices of corruption among public officials. One such index is based on the perception private firms have acquired, on the

basis of their experience, of the bribes people have had to pay officials in order to do business. The index (see Table 1)- which is on a scale of 1 (highly corrupt) to 10 (highly clean) - is less than 3.5 for most poor countries (African countries and Eastern Europe are among the worst) and greater than 7 for most rich countries (Scandinavian countries are among the best). It used to be argued that bribery of public officials helps to raise national income because it lubricates economic transactions. It does so in a corrupt world: if you don't pay up, you don't get to do business. But corruption isn't an inevitable evil. There are several poor countries where corruption is low. Having to pay bribes raises production costs; so less is produced. Citizens suffer, because the price they have to pay for products is that much higher.

Economists have speculated that government corruption is related to the delays people face in having the rule of law enforced. The thought is that delays are a way of eliciting bribes to hasten legal processes. To enforce a contract takes 415 days in the poor world, as against 280 days in the rich world. It may be that corruption is also related to government ineffectiveness. To register a business takes 66 days in the poor world, 27 days in the rich world. In poor countries registering property takes 100 days on average, while in rich countries the figure is 50 days. Some economists have suggested that government officials in poor countries create lengthy queues (that's government ineffectiveness) so as to elicit bribes from applicants if they want to jump those queues (that's corruption).

How do government corruption, ineffectiveness, and indifference to the rule of law translate into the kind of macroeconomic statistics we have been studying here? They leave their imprint on total factor productivity. Other things being equal, a country whose government is corrupt or ineffective, or where the rule of law is not respected, is a country whose total factor productivity is lower than that of a country whose government suffers from less of those defects. Some scholars call these intangible but quantifiable factors *social infrastructure*, others call them *social capital*.

2 Sustainable Economic Development

Economic growth is a good thing. It may not buy happiness, but it usually purchases a better quality of life. showed that growth in real GDP per capita comes hand in hand with improvements in the way people are able to live. But can economies grow indefinitely, or are there limits to growth? To put the question in a more contemporary form, is growth in real GDP compatible with sustainable economic development?

2.1 Conflicting Viewpoints

The question is several decades old. If discussions on it continue to be shrill, it is because two opposing empirical perspectives have shaped them. On the one hand, if we look at specific examples of natural resources (fresh water, ocean fisheries, the atmosphere as a carbon sink - more generally, ecosystems), there is strong evidence that the rates at which we are currently utilizing them are unsustainable. During the 20th century world population grew by a factor of four to more than 6 billion, industrial output increased by a multiple of 40 and the use of energy by 16, methane-producing cattle population grew in pace with human population, fish catch increased by a multiple of 35 and carbon and

sulfur dioxide emissions by 10. The application of nitrogen to the terrestrial environment from the use of fertilizers, fossil fuels, and leguminous crops is now at least as great as that from all natural sources combined. Ecologists have estimated that 40% of the net energy created by terrestrial photosynthesis is currently being appropriated for human use. These figures put the scale of our presence on Earth in perspective and reveal that Humanity has created an unprecedented disturbance in Nature in a brief period of a century or so.

On the other hand, it is often argued that just earlier generations in the West invested in science and technology, education, and machines and equipment so as to bequeath to the present generation the ability to achieve high income levels, the current generation is now in turn making investments that will assure still higher living standards in the future. It has been argued as well that the historical trend in the prices of marketed natural resources, such as minerals and ores, has been so flat that there isn't any reason for alarm. Economic growth has allowed more people to have access to potable water and enjoy better protection against water- and air-borne diseases. The physical environment inside the home has improved beyond measure with economic growth: cooking in the Indian sub-continent continues to be a major cause of respiratory illnesses among women. Moreover, natural resources can be so shifted round today, that dwindling resources in one place can be met by imports from another. Intellectuals and commentators use the term "globalization" to imply that location *per se* doesn't matter. This optimistic view emphasizes the potential of capital accumulation and technological improvements to compensate for environmental degradation. It says that economic growth, even in the form and shape it has taken so far, *is* compatible with sustainable development. This probably explains why contemporary societies are obsessed with cultural survival and are on the whole dismissive of any suggestion that we need to find ways to survive ecologically.

Broadly speaking, environmental scientists and activists hold the former view, while economists and economic commentators maintain the latter. It is no doubt banal to say that our economies are built in and on Nature, but it is an remarked-upon fact that most contemporary accounts of long run economic possibilities facing Humanity don't include *natural capital*. Nature doesn't feature in accounts of the macroeconomic history of nations because it doesn't appear in official publications of the vital statistics of nations. The extraction of minerals and fossil fuels is included in modern national accounts, but with the exception of agricultural land, natural capital makes very little appearance. Nature's services appear in economics text book in passing, only to be sidestepped. That is how things are in the literature on the theory and empirics of long term economic growth and the economics of poverty.

2.2 Natural Capital: Classification

Natural capital is of direct use in consumption (fisheries); of indirect use as inputs in production (oil and natural gas); or of use in both (air and water). The value of a resource is often derived from its usefulness (as a source of food, or as an essential actor in ecosystems - e.g., a keystone species); but there are resources whose value is aesthetic (places of scenic beauty), or intrinsic (primates, blue whales,

sacred groves), or a combination of all three (biodiversity). The worth of a natural resource could be based on what is extracted from it (timber), or on its presence as a stock (forest cover), or on both (watersheds).

Interpreting natural capital in an inclusive way, as I am doing here, allows us to add ecosystems to our list of capital assets. The services they produce include maintaining a genetic library, preserving and regenerating soil, fixing nitrogen and carbon, recycling nutrients, controlling floods, filtering pollutants, assimilating waste, pollinating crops, operating the hydrological cycle, and maintaining the gaseous composition of the atmosphere. A number of them have a global reach (the atmosphere), but many are localised (microwatersheds).

Pollutants are the reverse of resources. Roughly speaking, "resources" are "goods" (in many situations they are the sinks into which pollutants are discharged), while "pollutants" (the degrader of resources) are "bads". If over a period of time the discharge of pollutants into a sink exceeds the latter's assimilative capacity, the sink collapses. Pollution is thus the reverse of conservation. In what follows, we will use the terms *natural resources* and *environment* interchangebly.

2.3 Two Simple Exercises in Environmental Economics

In order to demonstrate that economics is capable of joining the environmental sciences in a seamless way, it will prove useful to begin with a discussion of two issues that are much in the news today. The first is the subject of an acrimonious debate between those who favour free trade and those who are opposed to it on grounds that it often hurts the poorest in the world's poorest regions. The second is the belief that because the economic effects of carbon dioxide emissions into the atmosphere are likely to be felt by a generation or two further down from us, we needn't do anything about climate change now.

Trade expansion and the environment

There should be little doubt today that, other things being equal, freeing trade enables economies to grow faster. A large body of empirical work testifies to that. There is some evidence too that the poor, *as a group*, also enjoy the fruits of faster growth. However, as the environmental consequences of economic growth are rarely assessed, the case for freeing trade remains unclear. If those consequences hurt many of the poorest in society, there is room for discussion about the merits of freeing trade without at the same time taking precautionary measures. Here is an example of how trade expansion can hurt.

An easy way for governments in poor countries that are richly covered in forests to earn revenue is to issue timber concessions to private logging firms. Imagine that logging concessions are awarded for the upland forest of a watershed. Deforestation contributes to an increase in siltation and the risk of floods downstream. If the law recognizes the rights of those who are harmed, the logging firm would have to compensate downstream farmers and coastal fishermen. But there is a gulf between the law and the enforcement of the law. When the cause of damage is miles away, when the timber concession has been awarded by the state, and when the victims are a scattered group of poor farmers and coastal

fishermen, the issue of a negotiated outcome usually doesn't arise. It can even be that those who are harmed do not know the underlying cause of their deteriorating circumstances. If the logging firm isn't required to compensate those suffering damage, the private cost of logging is less than the true cost of logging, the latter being the sum of the costs borne by the logging firm and all who are adversely affected. From the country's point of view, timber exports are underpriced, which is another way of saying that there is excessive deforestation upstream. It is also a way of saying that there is an implicit subsidy on the export, paid for by people who are evicted from the forest and by people downstream. The subsidy is hidden from public scrutiny; but it amounts to a transfer of wealth from the exporting country to those that import the timber. Some of the poorest people in a poor country would be subsidising the incomes of the average importer in a rich country.

Unfortunately, I can give you no idea of the magnitude of those subsidies, because they haven't been estimated. International organizations have the resources to undertake such studies; but, to the best of my knowledge, they haven't done so. The example shouldn't be used to argue against free trade, but it can be used to caution anyone who advocates free trade while ignoring its environmental impacts.

Discounting climate change

My second example concerns the emission of greenhouse gases and the global climate change it is inducing, the subject of continuing study by the International Panel on Climate Change (IPCC). I do not need to rehearse here the fact that the carbon concentration in the atmosphere today is above the highest level reached in the past 600,000 years. (I ignore the concentration of methane - another greenhouse gas.) If current trends in carbon emissions continue, its concentration is expected to reach 500 ppm (which is nearly twice the pre-industrial level - that is, CE 1800) by the middle of this century, and could reach as high a figure as 750 ppm (which is nearly thrice the pre-industrial level) by year 2100. A doubling of present day carbon concentration is expected by climate scientists to give rise to an increase in the mean global atmospheric temperature by 3-7 degrees Celsius. With a trebling of concentration, it could rise by 6-11 degrees. The scale and speed of such a change are so great, that the potential economic costs of global climate change will in all likelihood be huge. Nevertheless, when in 2004 eight eminent economists were invited to Copenhagen to offer advice on how the world community could most usefully spend $50 billion over a 5-year period, they placed climate change at the bottom of their list of ten alternatives.

Why did the economists do that? They did it because their reasoning was based on discounting future costs and benefits at a positive rate. Reducing global carbon emissions or investing in technologies for carbon sequestrtation would involve huge costs now, but the benefits from averting economic disruptions would be enjoyed only 50 to 100 years from now. Long-term interest rates on government bonds in the US have been 3-5% a year. When economists there evaluate *public* projects, they typically use such a figure to discount future benefits and costs, regarding it as the "opportunity cost of capital", the term being applied to the rate of interest that could be earned by investing in government bonds

rather than in the project whose benefits and costs are being evaluated. At discount rates of 3-5%, though, consumption benefits in the distant future look minute today. If you discount at 4% a year, a dollar's worth of additional consumption benefits 100 years from now would be worth less than 3 cents today; which is another way of saying that as a price for giving up $1 worth of consumption today, you would demand that more than $30 worth of consumption benefits be made available 100 years from now. A number of economic models of climate change have shown that if you use an annual discount rate of, say, 4%, the costs (which are negative benefits) are greater than the sum of the discounted benefits from curbing net carbon emissions. Doing something about climate change now, the calculations imply, would be to throw money away in a comparatively bad project.

Should the global community discount future consumption benefits at a positive rate? There are two reasons why it may be reasonable for the global community to discount future benefits at a positive rate. First, a future benefit would be of less value than that same benefit today if the global community is impatient to enjoy the benefit now. Impatience is a reason for discounting future costs and benefits at a positive rate. Second, considerations of justice and equality demand that consumption per capita should be smoothed across the generations. So, if future generations are likely to be richer than us, there is a case for valuing an extra dollar's worth of their consumption less than an extra dollar's worth of our consumption, other things being equal. Rising consumption per capita provides a second justification for discounting future costs and benefits at a positive rate.

Philosophers have argued that societal impatience is ethically indefensible, because it favours policies that discriminate against future generations merely on the grounds that they are not present today. Once we accept their argument, we are left with only the second reason for discounting future costs and benefits. But if rising per capita consumption provides the global community with a reason for discounting future consumption benefits at a positive rate, declining per capita consumption would provide it with a reason for discounting future consumption benefits at a *negative* rate.

Economists use positive discount rates in their models of climate change because the models *assume* that global consumption per head will continue to grow over the next 150 years and more even if net emissions of greenhouse gases follow current trends; which is to assume that climate change poses no serious threat to the future. But an increase in the mean global temperature by 3-5 degrees Celsius would take the biosphere into a climatic zone that has not been visited in *millions* of years on Earth. The possible consequences of such changes to our productive base are so huge, that it isn't to be an alarmist to question forecasts of continual economic growth even after Earth enters that zone. Suppose you fear that if nothing substantial is done today to discover ways to sequester carbon and to find alternatives to fossil fuels as sources of energy, there is a sizeable chance that global consumption per head, suitably weighted across regions and income groups, will decline - owing, say, to a big increase in the frequency of extreme weather events, more severe droughts in the tropics, the emergence of new pathogens, and degradation of vital ecosystems. You should then use a negative rate to discount future consumption

benefits. Notice though that applying a negative rate *amplifies* benefits in the distant future when viewed from the present, it doesn't attenuate them.

Let us perform a quick calculation to get a feel for orders of magnitude. Empirical evidence from societal and personal choices suggests that the rate a society ought to use to discount future consumption benefits is about 3 times the percentage rate of change of consumption per capita. Imagine that carbon emissions follow their current trends (which is often called "business as usual"). Consider a scenario in which global consumption per capita increases at an annual rate of 0.5% for the next 50 years and declines at 1% a year for the following 100 years. Under that scenario the global community ought to discount future consumption benefits at 1.5% a year for the next 50 years (3 times 0.5) and at *minus* 3% for the subsequent 100 years (3 times minus 1). A simple calculation now shows that a dollar's worth of additional consumption 150 years from now is worth $9 of additional consumption today. To put it another way, the global community should be willing to forego $9 worth of additional consumption today for an extra dollar's worth of consumption benefits 150 years in the future. The calculation reverses the message that has been conveyed by economic models of climate change.

There should be little doubt that private investors would be using a positive rate to discount their personal earnings even under the above scenario. They would be doing so because the interest rate offered by commercial banks on deposits would most likely remain positive. But there is no contradiction here. Under "business as usual", the atmosphere is an open access resource. So long as people are free to emit carbon dioxide, there will be a wedge between private rates of return on investment and the rates the world community ought to use to discount collective costs and benefits. The former could be positive even while the latter is negative. That wedge is a reason for controlling carbon emissions into the atmosphere and bringing the two rates closer to each other; it isn't a reason for claiming that the problem of global climate change should be shelved for the future.

2.4 GDP and the Productive Base

What we have just conducted are but a pair of finger exercises. Nevertheless, they have shown us how natural capital can be introduced in microeconomic reasoning. Let us see if it can be included in macroeconomic reasoning.

A famous 1987 report by an international commission (widely known as the Brundtland Commission Report) defined *sustainable development* as "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (*World Commission* 1987.) In this reckoning sustainable development requires that relative to their populations each generation should bequeath to its successor at least as large a *productive base* as it had itself inherited. Notice that the requirement is derived from a relatively weak notion of intergenerational justice. Sustainable development demands that future generations have no less of the means to meet their needs than we do ourselves; it demands nothing more. But how is a generation to judge whether it is leaving behind an adequate productive base for its successor?

It is easy to see why focussing on GDP won't do. An economy's productive base is its stock of capital assets and institutions. By capital assets we now mean not only manufactured capital, human capital, and knowledge, but also natural capital. We will presently discover what to look for in order to check whether an economy's productive base is expanding or contracting. It is evident though, that an economy's productive base will shrink if its stock of capital assets depreciates and its institutions aren't able to improve sufficiently to compensate for that depreciation. GDP is an acronym for *gross* domestic product. The word "gross" means that GDP ignores the depreciation of capital assets. It is certainly possible for a country's productive base to grow while its GDP increases (this will be confirmed when we come to study Table 2), which is no doubt a path of economic development we all would like to follow; but it is also possible for a country's productive base to *shrink* during a period when GDP grows (this also will be confirmed when we come to study Table 2). The problem is that no one would notice the shrinking if everyone's eyes were rivetted on GDP. If the productive base continues to shrink, economic growth will sooner or later stop and reverse sign. The standard of living will then decline, but no one would have suspected that a fall was in store. So, growth in GDP per head can encourage us to think that all is well, when it isn't. Similarly, it is possible for a country's Human Development Index (HDI) to increase even while its productive base shrinks (Table 2). This means that HDI too can mislead.

2.5 Market prices as signals of resource scarcity

You could counter that a fixation on GDP or HDI shouldn't prevent anyone from looking up prices. You could even argue that if natural resources really were becoming more scarce, their prices would have risen, and that would have signalled that all is not well. But if prices are to reveal scarcities, markets must function well. For many natural resources, markets not only don't function well, they don't even exist (we called them "missing markets" earlier). In some cases they don't exist because relevant economic interactions take place over large distances, making the costs of negotiation too high (e.g., the effects of upland deforestation on downstream farming and fishing activities); in other cases they don't exist because the interactions are separated by large temporal distances (e.g., the effect of carbon emission on climate in the distant future, in a world where forward markets don't exist because future generations are not present today to negotiate with us). Then there are cases (the atmosphere, aquifers, the open seas) where the migratory nature of the resource keeps markets from existing - they are *open access* resources; while in others, ill-specified or unprotected property rights prevent markets from being formed (mangroves and coral reefs), or make them function wrongly even when they do form (those who are displaced by deforestation aren't compensated). The side-effects of human activities that are undertaken without mutual agreement are called *externalities* by economists. Our dealings with Nature are full of externalities. The examples suggest that the externalities involving the environment are mostly negative, implying that the private costs of using natural resources are less than their social costs. Being underpriced, the environment is over-exploited. In such a situation the economy could enjoy growth in real GDP and improvements in HDI for a long spell even while its productive base shrinks. As proposals

for estimating the social scarcity prices of natural resources remain contentious, economic accountants ignore them and governments remain wary of taxing their use.

2.6 The environment: is it a luxury or necessity

It isn't uncommon to regard the environment as a luxury good, as in the thoughts expressed in prominent newspapers, that "economic growth is good for the environment because countries need to put poverty behind them in order to care," (*The Independent*, 4 December 1999), or that "... trade improves the environment, because it raises incomes, and the richer people are, the more willing they are to devote resources to cleaning up their living space," (*The Economist*, 4 December, 1999). But in the poor world the environment is an essential factor of production. When wetlands, inland and coastal fisheries, woodlands, forests, ponds, and grazing fields are damaged (owing to agricultural encroachment, nitrogen overload, urban extensions, the construction of large dams, resource usurpation by the state, or whatever), it is the rural poor who suffer most. Frequently, there are no alternative sources of livelihood for them. In contrast, for rich eco-tourists or importers of primary products, there is something else, often somewhere else; which means that there are alternatives. Degradation of ecosystems is like the depreciation of roads, buildings, and machinery - but with two big differences: (1) it is frequently irreversible (or at best the system takes a long time to recover), and (2) ecosystems can collapse abruptly, without much prior warning. Imagine what would happen to a city's inhabitants if the infrastructure connecting it to the outside world was to break down without notice. Vanishing water holes, deteriorating grazing fields, barren slopes, and wasting mangroves are spatially confined instances of corresponding breakdowns among the rural poor in poor countries. Modern economics helps to explain how an ecological collapse, such as the one that has been experienced in recent years in the Horn of Africa and the Darfur region of Sudan, can trigger rapid socio-economic decline.

2.7 Sustainable Development: Theory

Economic development is sustainable if, relative to its population, a society's productive base doesn't shrink. How can one tell whether economic development has been sustainable? We have noted that neither GDP nor HDI will tell us. So what index would do the job? A society's productive base is its institutions and capital assets. As we are interested in estimating the change in an economy's productive base over a period of time, we need to know how to combine the changes that take place in its capital stocks and in its institutions. Let us keep institutions aside for the moment and concentrate on capital assets.

Intuitively it is clear that we have to do more than just keep a score of capital assets (so many additional pieces of machinery and equipment; so many more miles of roads; so many fewer square miles of forest cover; and so forth). An economy's productive base declines if the decumulation of assets is not compensated by the accumulation of other assets. Contrarywise, the productive base expands if the decumulation of assets *is* (more than) compensated by the accumulation of other assets. The ability of an asset to compensate for the decline in some other asset depends on technological knowledge (e.g., double

glazing can substitute for central heating upto a point, but only upto a point) and on the quantities of assets the economy happens to have in stock (e.g., the protection trees provide against soil erosion depends on the existing grass cover). Clearly though, capital assets differ in their ability to compensate for one another. Those abilities are the *values* we would wish to impute to assets. We need to have estimates of those abilities. This is where an asset's *social productivity* becomes an item of interest. By an asset's social productivity we mean the net increase in *social well-being* that would be enjoyed if an additional unit of that asset were made available to the economy, other things being equal. Putting it another way, the social productivity of an asset is the capitalised value of the flow of services an extra unit of it would provide society. An asset's value is simply its quantity multiplied by its social productivity.

As we are trying to make operational sense of the concept of *sustainable* development, we must include in the term "social well-being" not only the well-being of those who are present, but also of those who will be here in the future. There are ethical theories that go beyond a purely anthropocentric view of Nature, by insisting that certain aspects of Nature have intrinsic value. The concept of social well-being I am appealing to here includes intrinsic values in its net if required. However, an ethical theory on its own won't be enough to determine the social productivities of capital assets, because there would be nothing for the theory to act upon. We need *descriptions* of states of affairs too. To add a unit of a capital asset to an economy is to perturb that economy. In order to estimate the contribution of that additional unit to social well-being, we need a description of the state of affairs both before and after the addition has been made. In short, measuring the social productivities of capital assets involves both evaluation and description.

Imagine now that you have adopted a conception of social well-being (e.g., by adding the well-beings of all persons) and that you have an economic scenario of the future in mind (e.g., business as usual). In principle you can now estimate the social productivity of every capital asset. You can do that by estimating the contribution to social well-being (that's the evaluative part of the exercise) an additional unit of each capital asset would make, *other things being equal* (that's the descriptive part of the exercise). Economists call social productivities of capital assets their *shadow prices*, to distinguish them from prices that are observed in the market. Although shadow prices pertain to commodities generally, not only to capital assets, we focus on capital assets here.

Shadow prices reflect the social scarcities of capital assets. In the world as we know it, estimating shadow prices is a formidable problem. There are ethical values we hold that are probably impossible to commensurate when they come up against other values that we also hold. This doesn't mean ethical values don't impose bounds on shadow prices; they do. Which is why the language of shadow prices is essential if we wish to avoid making sombre pronouncements about sustainable development that amount to saying nothing. Most methods that are currently deployed to estimate the shadow prices of ecosystem services are crude, but deploying them is a lot better than doing nothing to

value them.

The value of an economy's stock of capital assets, measured in terms of their shadow prices, is its *inclusive wealth*. The term "inclusive" serves to remind us not only that natural capital has been included on the list of assets, but also that externalities have been taken into account in valuing the assets. Inclusive wealth is the sum of the values of all capital assets. It is a number - expressed, say, in international dollars.

We can summarise by saying that an economy's inclusive wealth plus institutions constitute its productive base. If we now wish to determine whether a country's economic development has been sustainable over a period of time, we have to estimate the changes that took place over that period in its inclusive wealth and its institutions - relative to population of course. Earlier, we noted that changes in knowledge and institutions over time are reflected in movements in total factor productivity. So we break up the procedure for estimating changes in an economy's productive base relative to population during any period of time into five stages:

First, estimate the value of changes in the amounts and compositions of manufactured capital, human capital, and natural capital - which we will call *inclusive investment*. (If inclusive investment is found to be positive, we may conclude that manufactured capital, human capital, and natural capital, taken together, grew over the period.) Second, estimate the change in total factor productivity. Third, transform the two figures in a way that enables us to calculate the effects of the two sets of changes on the productive base. Fourth, combine the two resulting estimates into a single number that can be taken to reflect the change that took place in the economy's productive base. Fifth, make a correction for demographic changes to arrive at an estimate for the change that took place in the economy's productive base relative to population.

I have so worded the five steps that they apply to a study of the past. But, of course, the five steps can be applied with equal validity to forecasts of the future. The procedure outlined here is essential for anyone who wants to know whether the economic pathways we are currently pursuing can be expected to lead to sustainable development.

2.8 Has economic development in recent decades been sustainable?

Hamilton and Clemens (1999) have estimated inclusive investment in different countries during the past few decades. They have done that by adding net investment in human capital to existing country-wide estimates of investment in manufactured capital, and then substracting *dis*investments in natural capital from that sum. (That's step 1 above.) The authors used official estimates of net national saving as proxies for net investment in manufactured capital. For estimates of investment in human capital, they used expenditure on education as a proxy. To quantify disinvestments in natural capital, they considered net changes in the stocks of commercial forests, oil and minerals, and the quality of the atmosphere in terms of its carbon dioxide content. Oil and minerals were valued at their market prices minus extraction costs. The shadow price of global carbon emission into the atmosphere is the damage

caused by bringing about climate change. That damage was taken to be $20 per ton, which is in all probability a serious underestimate. Forests were valued in terms of their market price minus logging costs. Contributions of forests to ecosystem functions were ignored.

The list of natural resources in Hamilton and Clemens (1999) is very incomplete. It doesn't include water resources, fisheries, air and water pollutants, soil, and ecosystems. The notion of human capital he deployed is inadequate because health does not enter the calculus. And his estimates of shadow prices are very very approximate. Nevertheless, one has to start somewhere, and their's is a first pass at what is an enormously messy enterprise. In an earlier study (Dasgupta 2001), I used their estimates of inclusive investment to determine whether economic development in some of the major countries and regions in the rich and poor worlds has been sustainable in recent decades. What I want to do here is to study figures published recently by a group of ecologists and economists (Arrow *et al.* 2004), who refined my earlier estimates. Table 2 reports data that are in turn a refinement of Arrow *et al.* (2004). These data form a crude beginning to the study of sustainable development; but they are a start, and they reflect progress.

The places in question are sub-Saharan Africa, Bangladesh, India, Nepal, and Pakistan (all poor countries); China (a middle income country); and UK and US (both rich countries). The period under study is 1970-2000. The first column of numbers in Table 2 consists of refinements of the Hamilton-Clemens estimates of average inclusive investment as a proportion of GDP, expressed as percentages (step 1). The second column gives the average annual population growth rate. The third column gives estimates of annual growth rates of total factor productivity, which we are interpreting here as the annual percentage rate of change in a combined index of knowledge and institutions (that's step 2). I have used the figures in the first three columns to arrive at estimates of the annual percentage rate of change in the productive base per capita (that involves a combination of steps 3-5). They are given in the fourth column.

Before summarizing the findings, it will be useful to get a feel for what the numbers in the table are telling us. Consider Pakistan. During 1970-2000 inclusive investment as a proportion of GDP was 8.8% annually. Total factor productivity increased at an annual rate of 0.4%. As both figures are positive, we can conclude that Pakistan's productive base was larger in year 2000 than it had been in 1970. But take a look at Pakistan's population, which grew at a high 2.7% rate annually. The fourth column shows that Pakistan's productive base per capita declined in consequence, at an annual rate of 0.7%, implying that in year 2000 it was about 80% of what it was in 1970.

In contrast, consider the US. Inclusive investment as a share of GDP there was 8.9% a year, which is only a tiny bit larger than Pakistan's figure. Growth in total factor productivity (an annual 0.2%) was even lower than Pakistan's. But population grew only at 1.1% a year, meaning that the productive base per capita of the US grew at an average annual rate of 1%. Economic development in the US was sustainable during 1970-2000, while in Pakistan it was unsustainable.

Interestingly, if you had judged their economic performances in terms of growth in GDP per capita, you would have obtained a different picture. As the fifth column of Table 2 shows, Pakistan grew at a respectable 2.2% rate a year, while the US grew at only 1.1% a year. If you now look at the sixth column, you will find that the United Nations' Human Development Index (HDI) for Pakistan improved during the period. Movements in HDI tell us nothing about sustainable development.

The striking message of Table 2, however, is that during 1970-2000 economic development in *all* the poor countries on our list was either unsustainable or barely sustainable. To be sure, sub-Saharan Africa offers no surprise. Its inclusive investment was *negative*, implying that the region *dis*invested in manufactured, human, and natural capital, taken together, at 2.1% of GDP. Population grew at 2.7% a year and total factor productivity barely advanced (annual growth rate: 0.1%). Even without performing any calculation, we should suspect that the productive base per capita in sub-Saharan Africa declined. The table confirms that it did, at 2.9% annually. If you now look at the fifth column of numbers, you will discover that GDP per capita in sub-Saharan Africa remained pretty much constant. But the region's HDI showed an improvement - confirming once again that studying movements in HDI enables us to say nothing about sustainable development.

Pakistan is the worst performer in the Indian sub-continent, but the remaining countries in the region just barely made it when judged in terms of sustainable development. Inclusive investment in each country (Bangladesh, India, and Nepal) was positive, as was growth in total factor productivity. The two together imply that the productive base expanded in each country. But population growth was so high, that the productive base per capita just about grew - at annual percentage rates 0.1, 0.4, and 0.6 respectively. Even these figures are most likely to be overestimates. The list of items Hamilton and Clemens used in order to estimate inclusive investment didn't include soil erosion and urban pollution, both of which are thought by experts to be problematic in the Indian sub-continent. Moreover, the human desire to reduce risk, mentioned earlier, implies that downside risks of natural capital degradation ought to be given a higher weight than a corresponding chance that things will turn out to be better than expected. So, if we allow for risk aversion, estimates of inclusive investment would be lowered. One cannot help suspecting that economic development in the Indian sub-continent was unsustainable during 1970-2000. But you wouldn't know that from figures for GDP per capita and HDI there. The former grew in each country in the region and the latter improved.

Inclusive investment in China was 22.7% of GDP, a very large figure in the sample of countries in Table 2. Growth in total factor productivity was a high 3.6% annually. Population grew at a relatively low 1.4% annual rate. We shouldn't be surprised that China's productive base per capita expanded - as it happens, at 7.8% annually. Per capita GDP also grew at an annual rate of 7.8%, and HDI improved. In China, GDP per capita, HDI, and the productive base per head moved parallel to one another.

There is little to comment on the UK and US. Both are rich, mature economies. Inclusive investment during 1970-2000 was modest, but then so was population growth low. Growth in total factor

productivity was low. Although the figures imply that the productive base per capita expanded in both countries, we should be circumspect because, as noted earlier, Hamilton and Clemens costed carbon emissions at too low a rate. GDP per capita increased in both countries and HDI improved there.

The figures we have just studied are all rough and ready, but they show how accounting for natural capital can make a substantial difference to our conception of the development process. In Table 2 I have deliberately made conservative assumptions regarding the degradation of natural capital. For example, a price of $20 per ton of carbon in the atmosphere is almost certainly a good deal below its true shadow price (or cost). If we were instead to take the shadow price to be the not unreasonable figure of $50 per ton, all the countries in Table 2, with the exception of China, would show a decline in their productive base per capita during 1970-2000. The message is sobering: Over the past three decades, sub-Saharan Africa (home to 750 million people today) has become poorer if judged in terms of its productive base per capita; and economic development in the Indian sub-continent (home to over 1.4 billion people today) and in the UK and US was either unsustainable or just barely sustainable. That said, it would be wrong to conclude that people in poor countries should have invested more in their productive base by consuming less. The production and distribution of goods and services in the poor world are highly inefficient. It would be wrong to regard consumption and investment in the productive base there as competing for a fixed quantity of funds. Better institutions would enable people in the poor world to both consume more and invest more (inclusively, of course!).

3 What Have We Learnt?

When contemporary economists neglect to include ecological concerns in their analysis, the fault lies not in modern economics, but in my tribe. In this lecture I have tried to show you that ecological truths can be introduced without fuss into economic reasoning. I have done that by reporting work done among a small group of ecologists and economists that has developed the correct way to study economic progress - whether the study is for descriptive or for prescriptive purposes. The macroeconomic history of nations looks very different when Nature is included as a capital asset in production activities. The tentative conclusions I draw from the evidence from a sample of rich and poor nations are:

1. High population growth in the world's poorest regions (South Asia and sub-Saharan Africa) has been an obstacle to the achievement of sustainable economic development there. There are good reasons for believing that people in those regions are on average less wealthy now than they were 35 years ago.

Relatedly,

2. When population growth is taken into account, the accumulation of manufactured capital, knowledge, and human capital (health and education) has not compensated for the degradation of natural capital in South Asia and sub-Saharan Africa and, in all probability, even in the UK and US.

3. China is probably an exception to (1) and (2).

The conclusions are very tentative and there is much further work to be done in understanding

economic change. It is high time growth economists, demographers, governments, and international agencies took Nature seriously.

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Table 1

Rich and Poor

	Rich nations	Poor nations
Population (billions)	1.0	2.3
GDP per capita	$30,000	$2,100
Human Development Index	high	low
Annual population growth rate (%): 1966-2004	0.8	2.4
Annual growth rate of GDP per capita (%): 1966-2004	2.4	1.8
Total fertility rate (TFR)	1.8	3.7
Adult literacy (%) (female literacy (%))	>95 (>95)	58 (48)
Index of government corruption	low	high
Life expectancy at birth (years)	78	58
Under 5 mortality (per 1000)	7	120
Rural population (% of total population)	20	70
Agriculture's share in GDP (%)	5	25

Source: *World Development Indicators* (World Bank, 2005)

Table 2

The Progress of Nations

Country/Region		*% Annual growth rate 1970-2000*				
	I/Y[*] *(percentage)*	*Population (per head)*	*TFP*[†]	*Productive Base (per head)*	*GDP (per head)*	Δ *HDI*[††]
Sub-Saharan Africa	-2.1	2.7	0.1	-2.9	-0.1	+
Bangladesh	7.1	2.2	0.7	0.1	1.9	+
India	9.5	2.0	0.6	0.4	3.0	+
Nepal	13.3	2.2	0.5	0.6	1.9	+
Pakistan	8.8	2.7	0.4	-0.7	2.2	+
China	22.7	1.4	3.6	7.8	7.8	+
United Kingdom	7.4	0.2	0.7	2.4	2.2	+
USA	8.9	1.1	0.2	1.0	2.0	+

[*] inclusive investment as a share of GDP (average over 1970-2000).
[†] total factor productivity.
[††] change in HDI between 1970 and 2000.

Adapted from K. J. Arrow, P. Dasgupta, L. Goulder, G. Daily, P. R. Ehrlich, G. M. Heal, S. Levin, K.-G. Maler, S. Schneider, D. A. Starrett, and B. Walker, "Are We Consuming Too Much?", *Journal of Economic Perspectives*, 2004, Vol. 18, No. 3, pp. 147-172.