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INTRODUCTION TO SUSTAINABLE DEVELOPMENT

I. What Is Sustainable Development?

Sustainable Development as an Analytical and Normative Concept

Sustainable development is a central concept for our age. It is both a way of understanding the world and a method for solving global problems. Sustainable Development Goals (SDGs) will guide the world's economic diplomacy in the coming generation. This book offers you an introduction to this fascinating and vital field of thought and action.

Our starting point is our crowded planet. There are now 7.2 billion people on the planet, roughly 9 times the 800 million people estimated to have lived in 1750, at the start of the Industrial Revolution. The world population continues to rise rapidly, by around 75 million people per year. Soon enough there will be 8 billion by the 2020s, and perhaps 9 billion by the early 2040s (Sustainable Development Solutions Network [SDSN] 2013a, 2, 5).

These billions of people are looking for their foothold in the world economy. The poor are struggling to find the food, safe water, health care, and shelter they need for mere survival. Those just above the poverty line are looking for improved prosperity and a brighter future for their children.

Those in the high-income world are hoping that technological advances will offer them and their families even higher levels of wellbeing. It seems that the super-rich also jostle for their place in the world's rankings of richest people.

In short, 7.2 billion people are looking for economic improvement. They are doing so in a world economy that is increasingly interconnected through trade, finance, technologies, production flows, migration, and social networks. The scale of the world economy, now estimated to produce $90 trillion of output per year (a sum called the gross world product, or GWP), is unprecedented (SDSN 2013a, 2). By crude statistics, the GWP measures at least 200 times larger than back in 1750. In truth, such a comparison is difficult to make, since much of the world economy today consists of goods and services that did not even exist 250 years ago.

What we know is that the world economy is vast, growing rapidly (by 3–4 percent per year in scale), and highly unequal in the distribution of income within countries and between countries. Ours is a world of fabulous wealth and extreme poverty: billions of people enjoy longevity and good health unimaginable in previous generations, yet at least 1 billion people live in such abject poverty that they struggle for mere survival every day. The poorest of the poor face the daily life-and-death challenges of insufficient nutrition, lack of health care, unsafe shelter, and the lack of safe drinking water and sanitation.

The world economy is not only remarkably unequal but also remarkably threatening to Earth itself. Like all living species, humanity depends on nature for food and water, materials for survival, and safety from dire environmental threats, such as epidemics and natural catastrophes. Yet for a species that depends on the beneficence of nature, or on what the scientists call "environmental services," we are doing a poor job of protecting the physical basis of our very survival! The gigantic world economy is creating a gigantic environmental crisis, one that threatens the lives and wellbeing of billions of people and the survival of millions of other species on the planet, if not our own.

The environmental threats, we shall learn, are arising on several fronts. Humanity is changing Earth's climate, the availability of fresh water, the oceans' chemistry, and the habitats of other species. These impacts are now so large that Earth itself is undergoing unmistakable changes in the functioning of key processes—such as the cycles of water, nitrogen, and carbon—upon which life depends. We don't know the precise scaling, timing, and implications of these changes, but we do know enough to understand that they are extremely dangerous and unprecedented in the span of humanity's 10,000 years of civilization.

Thus we arrive at sustainable development. As an intellectual pursuit, sustainable development tries to make sense of the interactions of three complex systems: the world economy, the global society, and the Earth's physical environment. How does an economy of 7.2 billion people and $90 trillion gross world output change over time? What causes economic growth? Why does poverty persist? What happens when billions of people are suddenly interconnected through markets, technology, finance, and social networks? How does a global society of such inequality of income, wealth, and power function? Can the poor escape their fate? Can human trust and sympathy surmount the divisions of class and power? And what happens when the world economy is on a collision course with the physical environment? Is there a way to change course, a way to combine economic development with environmental sustainability?

Sustainable development is also a normative outlook on the world, meaning that it recommends a set of *goals* to which the world should aspire. The world's nations adopted SDGs precisely to help guide the future course of economic and social development on the planet. In this normative (or ethical) sense, sustainable development calls for a world in which economic progress is widespread; extreme poverty is eliminated; social trust is encouraged through policies that strengthen the community; and the environment is protected from human-induced degradation. Notice that sustainable development recommends a holistic framework, in which society aims for economic, social, and environmental goals. Sometimes the following shorthand is used: SDGs call for *socially inclusive and environmentally sustainable economic growth.*

To achieve the economic, social, and environmental objectives of the SDGs, a fourth objective must also be achieved: good governance. Governments must carry out many core functions to enable societies to prosper. Among these core functions of government are the provision of social services such as health care and education; the provision of infrastructure such as roads, ports, and power; the protection of individuals from crime and violence; the promotion of basic science and new technologies; and the implementation of regulations to protect the

environment. Of course, this list is just a brief subset of what people around the world hope for from their governments. In fact, all too often they get the reverse: corruption, war, and an absence of public services.

In our world today, good governance cannot refer only to governments. The world's multinational companies are often the most powerful actors. Our wellbeing depends on these powerful companies obeying the law, respecting the natural environment, and helping the communities in which they operate, especially to help eradicate extreme poverty. Yet as with governments, reality is often the reverse. Multinational companies are often the agents of public corruption, bribing officials to bend regulations or tax policies in their favor and engaging in tax evasion, money laundering, and reckless environmental damage.

Thus the normative side of sustainable development envisions four basic objectives of a good society: economic prosperity; social inclusion and cohesion; environmental sustainability; and good governance by major social actors, including governments and business. It's a lot to ask for, and there is no shortage of challenges to achieving sustainable development in practice. Yet the stakes are high. Achieving sustainable development on our crowded, unequal, and degraded planet is the most important challenge facing our generation. The SDGs must be the compass, the lodestar, for the future development of the planet during the period 2015 to mid-century.

Before proceeding further, let me give a very brief history of the concept of sustainable development. The term "sustainable" as applied to ecosystems goes back a long way. Fisheries managers, for example, have long used the concept of the "maximum sustainable yield" to denote the maximum fish catch per year consistent with a stable fish population. In 1972, at the UN Conference on the Human Environment in Stockholm, the challenge of maintaining sustainability in the context of economic growth and development was first brought to the global forefront. That same year, the blockbuster book *Limits to Growth*, published by the Club of Rome, argued forcefully that continued economic growth on the prevailing economic patterns would collide with the Earth's finite resources, leading to a future overshoot and collapse.

While 1972 put the challenge of sustainable development onto the global stage, the phrase itself was introduced eight years later, in an influential publication entitled *World Conservation Strategy: Living Resource Conservation for Sustainable Development* (1980). This pathbreaking publication noted in its foreword that

> human beings, in their quest for economic development and enjoyment of the riches of nature, must come to terms with the reality of resource limitation and the carrying capacity of ecosystems, and must take account of the needs of future generations.

The purpose of the document was to "help advance the achievement of sustainable development through the conservation of living resources" (iv).

The phrase was then adopted and popularized in the report of the United Nations Commission on Environment and Development, known widely by the name of its chairwoman, Gro Harlem Brundtland. The Brundtland Commission gave a classic definition of the concept of sustainable development, one that was used for the next twenty-five years:

> Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland 1987, 41).

This "intergenerational" concept of sustainable development was widely adopted, including at the Rio Earth Summit in 1992. One of the key principles of the Rio Declaration was that "development today must not threaten the needs of present and future generations."

Over time, however, the definition of sustainable development evolved into a more practical approach, focusing less on intergenerational needs and more on the holistic approach linking economic development, social inclusion, and environmental sustainability. In 2002, at the UN World Summit on Sustainable Development (WSSD) in Johannesburg, the WSSD Plan of Implementation spoke of "the integration of the three components of sustainable development—economic development, social development and environmental protection—as interdependent and mutually reinforcing pillars" (World Summit on Sustainable Development 2002, 2). The concept of intergenerational justice remains but is now secondary to the emphasis on holistic development that embraces economic, social, and environmental objectives.

This three-part vision of sustainable development was again emphasized on the twentieth anniversary of the Rio Summit. In the final outcome document for the Rio+20 Summit ("The Future We Want"), the aim of sustainable development was put this way:

> We also reaffirm the need to achieve sustainable development by: promoting sustained, inclusive and equitable economic growth, creating greater opportunities for all, reducing inequalities, raising basic standards of living; fostering equitable social development and inclusion; and promoting integrated and sustainable management of natural resources and ecosystems that supports inter alia economic, social and human development while facilitating ecosystem conservation, regeneration and restoration and resilience in the face of new and emerging challenges. (UN General Assembly 2012, para. 4)

The SDGs, called for in the same outcome document, were also based on the three-part framework. Here is how the SDGs were announced in "The Future We Want":

> [The SDGs] should address and incorporate in a balanced way all three dimensions of sustainable development and their inter-linkages . . . We also underscore that SDGs should be action-oriented, concise and easy to communicate, limited in number, aspirational, global in nature and universally applicable to all countries while taking into account different national realities, capacities and levels of development and respecting national policies and priorities . . . Governments should drive implementation [of the SDGs] with the active involvement of all relevant stakeholders, as appropriate. (UN General Assembly 2012, paras. 246–7)

I will discuss the SDGs in greater detail in the final chapter. Until then, I will use the concept of sustainable development in the current sense of a three-way normative framework, embracing economic development, social inclusion, and environmental sustainability. In addition, I will refer to sustainable development as an *analytical field of study*, one that aims to explain and predict the complex and nonlinear interactions of human and natural systems. I turn next to this analytical sense of the term.

Embracing Complexity

In addition to being a normative (ethical) concept, sustainable development is also a science of complex systems. A system is a group of interacting components that together with the rules for their interaction constitute an interconnected whole. The brain is a system of interacting neurons; the human body is a system of some 10 trillion individual cells, with those cells interacting in systematic ways in various organ systems (circulatory system, nervous system, digestive system, etc.); the cell itself is a system of interacting organelles; and the economy is a system of millions of individuals and businesses, bound together in markets, contracts, laws, public services, and regulations.

We talk about these systems as complex because their interactions give rise to behaviors and patterns that are not easily discernible from the underlying components themselves. The conscious brain cannot be reduced to a list of its neurons and neurotransmitters; functions such as consciousness depend on highly complex interactions of the component neurons. A living cell is more than the sum of the nucleus, ribosomes, and other components; the systems of metabolism, gene expression, and the like depend on highly complex interactions of the components. A growing economy is more than the sum of its individual businesses and workers. Complexity scientists speak of the *emergent properties* of a complex system, meaning those characteristics that emerge from the interactions of the components to produce something that is "more than the sum of its parts."

Complex systems have many unexpected characteristics. They often respond in a nonlinear way to shocks or changes, meaning that even a modest change in the components of the system can cause a large, perhaps catastrophic change in the performance of the system as a whole. A small change in the cell's chemistry can lead to its death; a small change in the physical environment may cause large and cascading changes to the relative abundance of the species in that environment. The failure of a single business can lead to a financial panic and a global downturn, such as occurred when the Lehman Brothers investment bank failed

in September 2008. A single bank failure, or a single infection, or a slight change in Earth's temperature, can lead to a chain reaction, positive-feedback process, which has explosive consequences.

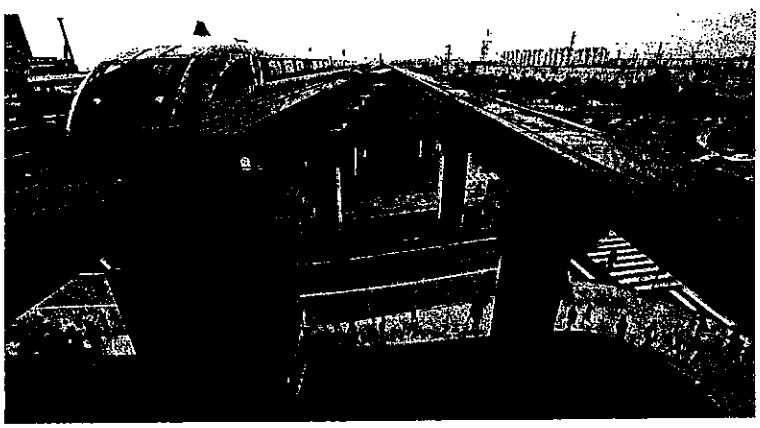
Sustainable development involves not just one but four complex interacting systems. It deals with a *global economy* that now spans every part of the world; it focuses on *social interactions* of trust, ethics, inequality, and social support networks in communities (including new global online communities made possible by revolutions in the information and communications technologies, or ICTs); it analyzes the changes to complex *Earth systems* such as climate and ecosystems; and it studies the problems of *governance*, including the performance of governments and businesses. In each of these complex systems—economic, social, environmental, and governance—the special properties of complex systems, such as emergent behavior and strong, nonlinear dynamics (including booms and busts), are all too apparent.

Complex systems require a certain complexity of thinking as well. It is a mistake to believe that the world's sustainable development problems can be boiled down to one idea or one solution. A complex phenomenon such as poverty in the midst of plenty has many causes that defy a single diagnosis or prescription, just as in the cases of environmental ills or communities torn asunder by mistrust and violence. Medical doctors are trained to understand and respond to the complex system known as the human body. Medical doctors know that a fever or a pain can have countless causes. Part of the job of a skilled medical doctor is to make a differential diagnosis of the specific cause of a fever in a particular patient. A skilled sustainable development practitioner needs to be a complex-systems expert in the same way, acknowledging the complexity of the issues and looking to make a specific diagnosis of each specific case.

The Role of Technological Change

The Maglev in Shanghai (figure 1.1) is a remarkable piece of technology that carries people at speeds of more than 200 miles per hour to and from Shanghai City and its international airport. It is a product of joint work between engineering companies from Europe and China and has been operating for the past decade. It is an example of how new technology can help to achieve sustainable development by improving transport services and energy efficiency, and eventually enabling a shift to a clean, low-carbon energy system. The maglev, unlike earlier generations of rail, is powered by electricity rather than by coal or petroleum. If and when the electricity that powers the maglev is eventually produced with a low-carbon primary energy source, rather than the coal that today dominates electricity generation in China, the electric-powered intercity rail will also promote the shift from fossil fuels to safer low-carbon energy sources such as wind and solar power (which are much less polluting and do not result in human-induced climate change, as discussed later).

Throughout our study of sustainable development we will note three aspects of technology. First, technological advances are the main driver of long-term global economic growth. The rapid growth of the world economy since 1750 is the result of 250 years of technological advances, starting with the steam engine and steam-powered transportation, the internal combustion engine, electrification, industrial chemistry, scientific agronomy, aviation, nuclear power, and today's ICTs.



1.1 The maglev train in Shanghai

Without these advances, the world economy and world population would have stopped growing long ago.

Second, technological advances often have negative side effects, even when their direct effects are enormously positive. The burning of coal is both the emblem of the Industrial Revolution and the root of our current environmental crisis. One can say that coal enabled modern civilization through the invention of the steam engine and the harnessing of fossil fuels for motive force. Yet coal is now used on such a scale, and with such dire side effects, that it endangers civilization itself. In 2010, humanity emitted around 14 billion tons of carbon dioxide (CO_2) through coal burning, close to half of the world's total emissions of CO_2 due to fossil fuels. Unless coal is phased out rapidly or used with new technologies (such as carbon capture and sequestration, discussed later), the damage to the planet and the global economy will be overwhelming.

Third, technological advance is, at least to some extent, under human guidance. Sometimes technological advance is portrayed as a great lottery, determined by the luck of the draw or the skill of individual inventors and scientists. Alternatively, technological advance is sometimes described as merely following the demands of the market. Companies invest in research and development (R&D) in order to pursue profits. We end up with research on challenges sought by the marketplace, not necessarily those of vital importance for the poor or for the environment. Yet there is another side to technological change, the idea that it can be *directed* toward human goals through a deliberate, goal-based interaction of public and private R&D efforts.

We are used to the idea that governments steer technology for "reasons of state"—that is, for military purposes. Governments have long hired engineers and inventors to design and build new weapons and defenses, many involving pioneering breakthroughs in technology. World War I heralded major advances in aviation; and World War II brought advances in computers, radar, semiconductors, rocketry, antibiotics, communications, semiconductors, and countless other advances led by state-supported research, including America's Manhattan Project, which brought together world-renowned physicists to design and construct the first atomic bombs.

Of course, we should greatly prefer to achieve technological advances through peaceful means. And indeed, there is a distinguished track record of government support for civilian technological advances (though often governments had military purposes also in mind even in these civilian breakthroughs). In recent decades, the Internet, information technology, aviation, space technology (such as global positioning systems), genomics, nanotechnology, and countless other areas of technological advance owe their development in significant measure to government support. In the age of sustainable development, we will need such directed technological change in order to develop new technologies for sustainable energy, transport, construction, food production, health delivery, education, and more. Governments will rely on many policy tools to drive innovations in a targeted direction, including the public financing of R&D, direct research in public laboratories, regulations, prizes for new inventions, and modifications of patent laws (e.g., to encourage R&D on specific diseases).

Sustainable Development as a Normative Approach

Sustainable development is a way to understand the world as a complex interaction of economic, social, environmental, and political systems. Yet it is also a normative or ethical view of the world, a way to define the objectives of a well-functioning society, one that delivers wellbeing for its citizens today and for future generations. The basic point of sustainable development in that normative sense is that it urges us to have a holistic vision of what a good society should be. The easy answer for many people is that a good society is a rich society, one in which higher incomes are the ultimate purpose of economic and political life. Yet something is clearly too limited in such a view. Suppose a society was rich on average because one person was super-rich while the rest were in fact very poor. Most people would not regard that as a very attractive society, one that brings wellbeing to the citizenry. People care not only about the average income but about the income distribution as well.

There are at least five kinds of concerns about the distribution of wellbeing. The first is extreme poverty. Are some people still exceedingly poor in the midst of plenty? The second is inequality. Are the gaps between the rich and poor very wide? The third is social mobility. Can a poor person today hope to achieve economic success in the future, or are the practical barriers to advancement too high?

The fourth is discrimination. Are some individuals such as women, racial minorities, religious minorities, or indigenous populations disadvantaged by their identity within a group? The fifth is social cohesion. Is the society riven by distrust, animosity, cynicism, and the absence of a shared moral code? Sustainable development takes a view on these issues, calling on society to aim for the end of extreme poverty; the reduction of glaring gaps of wealth and poverty; a high degree of social mobility, including good life chances for children born into poverty; the absence of discrimination including by gender, race, religion, or ethnicity; and the fostering of social trust, mutual support, moral values, and cohesion. We can summarize these objectives with the term *social inclusion*.

Another aspect of a good society is being a good steward of the natural environment. If we break the physical systems of water and biodiversity, if we destroy the oceans and the great rain forests, we will lose immeasurably. If we continue on a path that fundamentally changes the Earth's climate, we are going to face grave dangers. Therefore, from a normative perspective, environmental sustainability certainly seems right and compelling if we care, as we should, about the wellbeing of our children and our children's children and future generations.

We also care about how our government functions. Good governance and the rule of law create a sense of security and wellbeing. On the other hand, corruption, lawlessness, untrustworthy politicians, unfair government services, significant discrimination, insider dealing, and so forth create a lot of unhappiness. Careful studies have confirmed that across the world people feel happier and more satisfied with life when they trust their government. Unfortunately, in many places in the world, people do not trust their governments to be honest and fair and to keep them basically secure, and they have all too many valid reasons for that distrust.

From a normative perspective then, we could say that a good society is not only an economically prosperous society (with high per capita income) but also one that is also socially inclusive, environmentally sustainable, and well governed. That is my working definition of the normative objectives of sustainable development. It is the point of view endorsed by the SDGs adopted by the UN member states. The fundamental question is how to take our knowledge of the interconnections of the economy, society, the environment, and governance and apply it to determine how to produce prosperous, inclusive, sustainable, and well-governed societies; that is, how do we achieve the SDGs? We shall see that there are indeed some powerful ways to achieve sustainable development as a shared set of goals for the planet.

Trade-offs Versus Synergies In Economic, Social, and Environmental Goals

The conventional view is that there are important trade-offs in pursuing economic, social, and environmental goals. For example, it is conventionally believed that society can aim to be rich, or it can aim to be equal; but if it aims for more equality, it will end up less rich. In such a view, income and equality are *substitutes*. In colloquial terms, the debate is often over whether to "grow the economic pie" or to "divide the pie more equally." A similar trade-off is often perceived to exist regarding the environment. A poor society, it is said, must choose between growth and the environment.

Economists often use the terms "efficiency" and "equity" to describe such choices. Efficiency means the absence of waste in the economy. There is no way to raise one person's income or wellbeing without lowering someone else's. The pie, in essence, is as large as possible. Equity means fairness in the distribution of the pie, remembering that standards of fairness may differ across individuals. To restate the common view described above, there is a trade-off between efficiency and equity. Societies that aim to be fairer, in that conventional view, inevitably introduce inefficiencies into the economy, leading to a waste of resources. For example, a tax on rich people to distribute income to the poor may lower the work incentive of both the rich (who must pay part of their income in taxes) and of the poor (who have less incentive to work). The result may be fairer but at the cost of efficiency and lower output.

That view is much too pessimistic. We will see throughout this book why investing in fairness may also be investing in efficiency, and why attention to sustainability can be more fair and more efficient at the same time. Here are two easy examples. Suppose the tax on the rich is used not for consumption by the poor but for the education and health of the poor. The investments in health and education may well have a very high return for the poor, enabling them to be much

more productive. If the work effort of the rich is little affected by the tax, while the productivity of the poor is strongly boosted, the result may easily be more efficiency and more equity. Similarly, an investment in pollution control may raise productivity of the workforce by cutting disease and absenteeism, especially of the poor who are living in the most polluted conditions. Pollution control thereby achieves three aims: high output, more fairness, and more sustainability. In these cases, sustainable development offers *synergies* rather than trade-offs in the pursuit of efficiency, equity, and sustainability.

II. An Introduction to Economic Growth

Measuring the Size of the Economy

Economists typically summarize a country's overall economic development by gross domestic product (GDP) per person. The GDP measures the market value of total production within the country in a given time period, usually a year. Gross domestic product per capita (GDP per person) is simply GDP divided by the population. Since GDP is the size of the overall economic pie, the GDP per capita is the size of the average slice per person. Of course, the actual income distribution in any country will be uneven. Some households will have a very large slice of the pie, while others may receive no more than mere crumbs. Nonetheless, the average slice, the GDP per capita, is fairly closely though imperfectly correlated with other measures of national wellbeing, such as life expectancy, levels of education, quality of infrastructure, and levels of personal consumption spending.

There are a few quick points to mention about the measurement of GDP. First, GDP measures the production inside the boundaries of a country. This is different from the income earned by residents of the country. Suppose the country is an oil exporter, and the government owns two-thirds of the oil, while foreign companies own one-third. The GDP would count all of the oil produced within the country, but national income would include only the two-thirds of the oil owned by the government. We give the name gross national product (GNP) to the income-based measure. In this example, GNP would be less than GDP.

Second, the GDP measures output at market prices. For each output in the economy, such as bushels of grain, production of automobiles, sales of haircuts, and rentals of apartments, the quantity produced is multiplied by the price per unit, to calculate the value of production. These are summed to calculate the GDP. At this level, the GDP of each country is expressed in the national currency, such as dollars, pesos, euros, yen, yuan, won, and others. To compare across countries, the national currency units are converted to U.S. dollars, using the market exchange rate. We then have a common standard for comparing the GDP across countries. Dividing by each nation's population, we find the GDP per capita, which gives an indication of the relative living standards across countries (remembering that living standards will vary within each country based on the distribution of income across households).

Yet there is a problem with this comparison. The prices of individual products differ across countries, even when expressed in U.S. dollars. Suppose that in the first country, barbers sell $50 million worth of haircuts, while in the second, they sell $25 million. If the price of haircuts is the same across the two countries, we would be right to conclude that the first country enjoys twice the number of haircuts sold as the second. Yet if the market price of haircuts is twice as high in the first country, then the number of haircuts is actually the same, even though the sales volume in the first country is twice as high.

When we compare GDPs we want to compare the real volume of goods and services, not the difference merely due to market prices. In order to make a good comparison of GDP across countries, therefore, statisticians have decided to use a common set of "international prices" to sum up the production and consumption in each country. This adjusted measure is called the GDP at purchasing power parity (PPP). The use of a common set of international prices assures us that $1 of GDP in every country, when measured at PPP (or at international prices), has an equal purchasing power in terms of actual goods and services.

Third, we must also note GDP measures only the goods and services transacted in the market economy, not those that take place outside of the marketplace, such as production that occurs within the home. When a mother looks after her own children, the home day care is not counted as GDP. If the mother looks after the neighbor's child for a fee, however, that day care is counted as part of the GDP.

Also, GDP does not measure the "bads" or harms that often accompany production, such as the costs of industrial pollution or destruction by war. Therefore, GDP per person is only a rough indicator of true economic wellbeing per person. Plenty of terrible things—pollution, natural disasters, war—may afflict people in high-income countries without GDP reflecting those costs to society.

Defining Economic Growth

Ask an economic policy maker almost anywhere in the world about the country's main economic goal, and the answer will typically be "economic growth." Every day, the newspapers recount the recent growth rates of the major economies, as well as commentaries about the prospects for future growth. Yet what exactly is being measured by economic growth?

Economic growth, in simplest terms, measures the change in the GDP over a given period, for example, the current year relative to the past year or the current quarter of the year (January–March) compared with the preceding quarter (October–December). Economic growth signifies an increase in GDP.

Once again, we must immediately highlight some details. If the GDP rises by 100 percent (i.e., doubles in size), but the population also doubles, then the size of the average slice of the economic pie remains unchanged. Our interest in growth is therefore typically in the rise of GDP per capita rather than GDP by itself.

Moreover, we are interested in the rise of output of actual goods and services, not just the prices of goods and services. Here is an example. If the country produces one ton of steel, at $500 per ton, the contribution to GDP is $500. If the price of steel goes up to $1,000 per ton, while production remains at one ton, the contribution of steel to GDP rises to $1,000, even though there is no change in the actual production of the economy. Therefore, we generally are interested not in GDP at current prices (whether domestic or international), but GDP at constant prices. For example, we might decide that for the next several years, every ton of steel will be measured at a constant price of $500, even if the actual market price fluctuates. We call this GDP at constant prices. For the reasons described, we are in fact typically interested in "GDP at constant international prices" or "GDP at PPP in constant prices."

Why are we so interested in GDP per capita at constant international prices? As mentioned earlier, that measure tends to be related to several other indicators of prosperity. When GDP per capita increases, economic wellbeing tends to rise. Richer countries—those with a higher GDP per person—tend to have higher material wellbeing on average than poorer countries. People in richer countries tend to have higher consumption levels, greater food security, longer lives, and greater protection from diseases and environmental catastrophes. Chances of violence and war are lower. And people living in richer societies also tend to express greater satisfaction when asked for subjective assessments of their lives, as discussed in the next chapter.

Yet for many reasons, some already mentioned and others that will be mentioned later, the rise in GDP per capita is *far from a perfect measure of wellbeing*. It is quite conceivable that GDP per capita rises but that many people in the country end up being worse off. That could be true, for example, if only a small part of the society is recipient of the higher production. It could also be true if the rise in market-based output is offset by "bads" occurring outside the market, for example, environmental destruction such as air and water pollution.

Still, let us focus on the long-term trajectory of GDP per capita measured at constant international prices. The good news is that the world economy in total has tended to grow over the course of many decades. This means that if we add up the GDP (at constant international prices) of every country, and call the result the GWP, and then divide by world population to find GWP per person, we find that GWP per capita has been rising fairly consistently by around 2 to 3 percent per year. In turn, this global growth, reflecting the growth of national economies as well (using GDP per capita as the measurement), has been associated with many other gains in material wellbeing, such as improved health, better education, and more food security (though also more obesity, alas).

A handy rule of thumb for economic growth, and indeed for any kind of growth, is called the "rule of 70." The idea is the following. Consider the growth rate of the world economy, say a 2 percent per year increase of the GWP per person. If we take 70 divided by the annual growth rate, in this case 70 divided by 2, or 35, we determine the number of years it takes for the economy to double in size. So an economy growing at 2 percent per year will double in 35 years (= 70/2); if the global growth heats up to 4 percent per year, the doubling time therefore drops by half, to 17.5 years (= 70/4).

Now the key point is that the world economy has been growing consistently since the start of the Industrial Revolution in the middle of the eighteenth century. Angus Maddison, the late economic historian, did a great service for the economics profession by estimating the GDP per person over the long time period from the start of the Common Era (1 C.E.), with the most detailed data after 1820. He measured GDP in each period and country using the same standard: international prices of 1990. By that measure, the GWP rose from $695 billion in 1820 to around $41 trillion by 2010. During that same period, the world population rose from around 1.1 billion to 6.9 billion. Therefore, the GWP per capita (in constant 1990 international dollars) increased from $651 to $5,942 in Maddison's estimates (Maddison 2006).

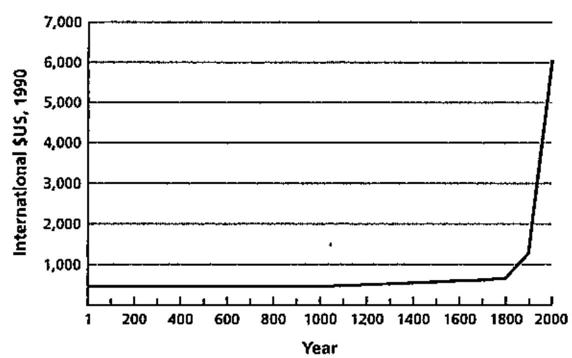
How fast is that growth on an annual basis? Note that there are 190 years between 1820 and 2010. Therefore, we can find the average growth rate between 1820 and 2010 by solving the following equation:

$$(\$\text{GWP per person in 2010})/(\$\text{GWP per person in 1820}) =$$
$$\$5942/\$651 = (1+g)^{190}$$

Solving for the growth rate g, we find that $g = 1.1$ percent per annum is the average annual growth rate since 1820. If we make exactly the same calculation for the years 1970 to 2010, we find that the more recent growth rate is even higher, at 1.5 percent per annum.

Figure 1.2 shows an admittedly rough estimate of GWP per person, measured at constant international dollars, over a *very long* time period, specifically from 1 C.E. to 2010. Of course, the actual GWP per person in earlier centuries is based on rough estimates rather than precise data. Still we see something absolutely extraordinary about this graph. During most of the history of the past two millennia, there was little or no economic growth. GWP per person only started to rise around 1750 and then only very gradually at the beginning. (Note that Maddison presents estimated world output for 1700 and 1820, but not for the year 1750.) The whole story of economic growth in human history is a recent one, stretching over little more than two centuries! Economic historians call the period since 1750 the "age of modern economic growth." This period is the central period of our study. One can see from figure 1.2 that even though the Industrial Revolution began in Britain sometime in the middle of the eighteenth century, it became noticeable at the global level only in the nineteenth century (hence Maddison's more detailed data starting only in 1820).

We can say the following now, to be elaborated later. For most of human history, output per person was at a very low level, just around the level needed to survive. Most of humanity lived on farms and grew food for their own subsistence. In most years, the food was enough to keep them alive. In bad years, with droughts or floods or heat waves or pests, the harvest might fail, and people would die, sometimes in large numbers. Poor harvests might also make the population more susceptible to infectious diseases, since malnourishment weakens the body's immune system. Starting around 1750, something fundamentally new began to occur: positive economic growth. We will see that economic growth started only in a few places, including Great Britain and the United States. Eventually it spread around the world, though quite unevenly.

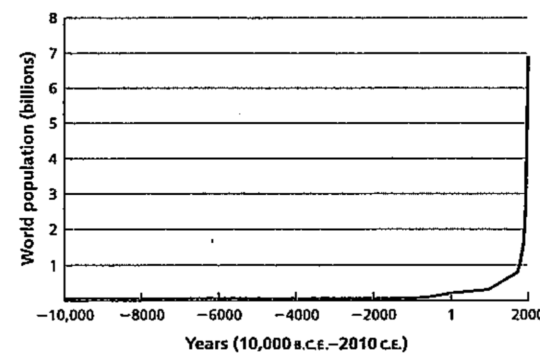


1.2 Gross world product per capita (1990 International Dollars)

Source: Bolt, J., and J. L. van Zanden. 2013. "The First Update of the Maddison Project: Re-Estimating Growth Before 1820." Maddison Project Working Paper 4.

The rise in GWP was first associated with the rise of industry, such as coal mining, steelmaking, and textile production. Indeed, we usually call the first takeoff of economic growth from around 1750 to 1850 the Industrial Revolution, with a capital "I" and "R." More recently, after 1950 or so in the high-income countries, the rise in GWP has been associated with the rise of services, such as the banking system. The overall result is that the world's output per person, or GWP per capita, lifted above the subsistence level and over a period of roughly 250 years, grew by a factor of around 30. In some countries, the increase has been a factor of around 100.

Figure 1.3 shows something else that is also astounding and that seems to follow a similar course. This graph looks quite like figure 1.2, but instead of measuring GWP per person, it measures the world population over a very long stretch of time, in this case all the way back to the presumed beginning of civilization, around 12,000 years before the present day (sometimes called 12,000 B.P.). This is the time when human beings shifted from hunting and gathering their food to growing it in one place; the change from nomads shifting locations to find food to farmers living in fixed villages. The period before agriculture is known as the



1.3 Global population (10,000 B.C.E.–present)

Source: Bolt, J., and J. L. van Zanden. 2013. "The First Update of the Maddison Project: Re-Estimating Growth Before 1820." Maddison Project Working Paper 4.

Paleolithic Era (*Paleo* = old + *lithic* = stone). The period after the start of agriculture is known as the Neolithic Era (*Neo* = new + *lithic* = stone).

What we see is that just like GWP per capita, the global population changed fairly little over very long stretches of time, always remaining well under 1 billion people. From 10,000 B.C.E. to around 2000 B.C.E., the human population was well under 100 million. Around 1 C.E., at the time of the Roman Empire, the world population according to Maddison's estimate was around 225 million. As of 1000, it was 267 million, on Maddison's best estimate; in 1500, around 438 million. It reached 1 billion around 1820. The world population therefore rose perhaps 4 times in the 18 centuries between 1 C.E. and 1820, implying an annual growth rate of just 0.08 percent per year. For most people in most of history, population seemed relatively unchanged over the course of a lifetime, indeed many lifetimes. The only changes were due to mass deaths from wars, famines, and plagues, followed by subsequent recoveries of population to more "normal" levels.

Then, in the same era as the Industrial Revolution, population broke free of its ancient restraints. At that point in history, the population curve turns up remarkably steeply. Around 1820 or so, humanity reached the great milestone of a billion people on the planet, then from 1820 to around 1930, in roughly one century, the second billion was added. Then the numbers really started to soar. In just 30 years, from 1930 to 1960, the third billion was added. The world went from 3 billion in 1960 to 4 billion in 1974, 5 billion in 1987, 6 billion in 1999, and 7 billion in the year 2011. Notice that the recent increments of 1 billion have occurred in roughly dozen-year intervals!

One clear reason for the rise in the world's population is the increased ability to grow more food and feed a rising population. Just as humanity learned to harness technology for industrialization, it learned to harness technology to raise food production. Since 1750 or so, farmers have been able to grow more food thanks to better seed varieties; better farming techniques (such as rotating crops through the years to maintain soil fertility); chemical fertilizers to boost soil nutrients; and machinery to sow seeds, harvest crops, process foodstuffs, and store and transport food to cities.

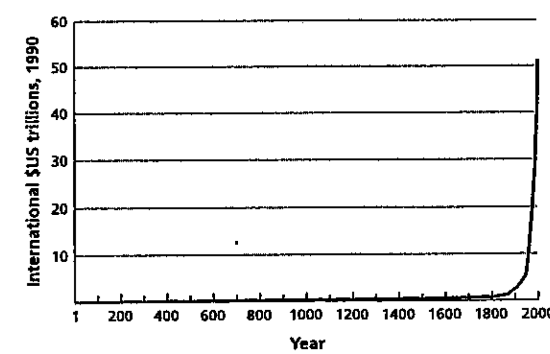
We are on track to reach 8 billion around 2024 or 2025, and 9 billion sometime in the early 2040s. After that, the numbers become far more uncertain but

will probably continue to rise, at least on present patterns of fertility (childbearing) and mortality (deaths). The rise in population since the early 1800s is absolutely astounding, unprecedented in human history, just as with GWP per person. The fundamental fact is that modern economic growth and global population increases have tended to come side by side, although the relationship between the two is complicated, as we shall learn.

The age of modern economic growth is one of rising output per person combined with rapid overall population growth. Together, those two dynamics, more income per person and more people on the planet, have meant a massive expansion of total economic activity. Indeed, it is an obvious relationship that total output in the world, the GWP, is equal to the output per capita multiplied by the world's population:

$$\text{GWP} = \text{GWP per capita} \times \text{world population}$$

Figure 1.4 shows Maddison's estimates of GWP production expressed in constant 1990 international dollars. Since GWP per capita and population both have



1.4 Growth of gross world output (international prices of 1990)

Source: Bolt, J., and J. L. van Zanden. 2013. "The First Update of the Maddison Project: Re-Estimating Growth Before 1820." Maddison Project Working Paper 4.

the same astounding pattern of nearly no change during 1 C.E.–1800, and then a sharp upturn, the graph of GWP has the same characteristic shape. World output has soared around 240 times since 1800. This has been a huge boon to average wellbeing (e.g., longer life expectancy), industrialization, urbanization, and yes, environmental threats as well.

The Recent Growth of China

Let's look at what growth really means in one very important case. There has been no exemplar of rapid economic growth more remarkable than China. China's growth is superlative in every aspect. As the world's most populous country, with 1.3 billion people, anything major that happens in China is earthshaking, but since 1978, China has also been among the fastest-growing economies in world history. When Deng Xiaoping came to power at that time, China undertook some basic market reforms that put the country on a trajectory of extraordinary economic growth, averaging roughly 10 percent per year in GDP growth.

Remember the rule of 70. A growth of 10 percent means that China has been doubling its GDP roughly every 7 years (= 70/10). This is absolutely astounding. Since China has grown at this torrid rate for almost 35 years, that is roughly 5 doublings (= 35 years/7 years per doubling). That in turn implies that the economy has grown roughly by a factor of 2^5 (or 32 times) since Deng Xiaoping opened the Chinese economy to market forces and international trade! In per capita terms, the growth is only slightly less impressive, at roughly 9 percent per annum, or 11.8 times overall between 1978 and 2013.

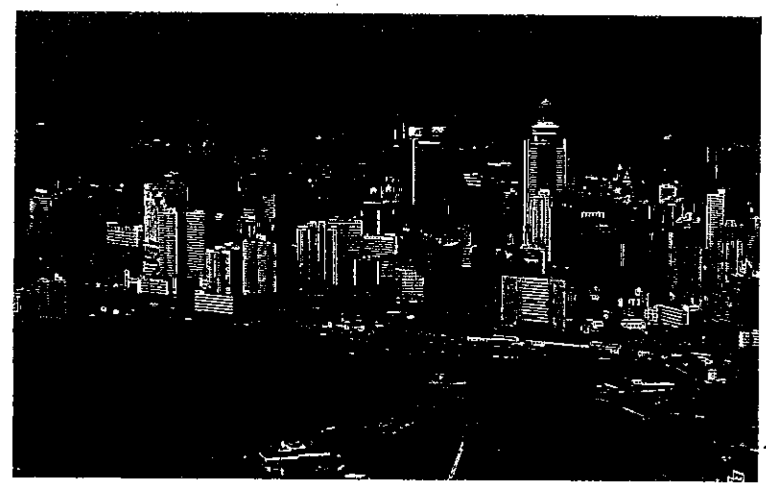
What does such extraordinary growth signify? To appreciate China's accomplishment, take the example of Shenzhen, which is a city very close to Hong Kong in southern China. In 1980, Shenzhen was a small, mainly rural village of some 30,000 people, as seen in figure 1.5.

Compare that with Shenzhen today, shown in figure 1.6.

Now, with nearly 12 million people, this modern metropolis is incomparable with its roots just three decades earlier. This kind of torrid growth is characteristic of China's eastern seaboard, where coastal cities became powerhouses of international trade. More than 200 million people have flocked from the countryside to

1.5 Shenzhen, China, in 1980

"Looking northwest . . . ," Leroy W. Demery, Jr., Flickr. Used with permission.



1.6 Shenzhen, China, in 2002

Reuters.

the cities in search of new jobs in industry and services. China has become the world's largest trading country and the industrial workshop of the world.

China's experience has the hallmarks of modern economic growth, albeit in a turbocharged version. The economy has proceeded from rural to urban, from agricultural to industrial and service-oriented. It has gone from high fertility rates (many children per woman) to low fertility rates, and from high child mortality to low child mortality. Life expectancy has soared, public health has improved, and educational attainment has gone up steeply. With its vast population and strong educational orientation, China now turns out more PhDs per year than any other place in the world. And all of this has happened in the span of just a bit over three decades. This is the kind of remarkable experience that inspires many countries to aim to end poverty within their borders.

We must not leave the impression that all is well with China's economic growth. There have been at least three serious downsides. First, the rapid transition from rural to urban, and from farming to industry and services, has disrupted the lives of hundreds of millions of people, causing mass migration within China and disrupting families, as fathers and mothers often went off to find work in the cities and left their children with grandparents in the countryside. Second, the inequality of income has soared, as urban workers have advanced in living standards, while the incomes of those left behind in the countryside have often stagnated. Third, the physical environment has been devastated, with massive pollution accompanying China's massive industrialization. Indeed, as we shall see, the pollution has become so bad that it is causing widespread disease and premature deaths, especially from heart and lung diseases, stroke, and cancers, slowing China's gains in life expectancy. China, in short, has achieved rapid economic growth but has not yet achieved sustainable development, meaning growth that is also socially inclusive and environmentally sustainable.

Improvements in Global Health

Global growth in GWP per capita has been accompanied by another positive development: the improvement in public health. Higher incomes have meant improved food security for many (as well as unhealthy diets leading to obesity). Advances in technology in agriculture and industry have also been accompanied

by rapid advances in health technologies, including medical advances such as antibiotics, vaccinations, diagnostics, and vast improvements in surgery, as well as advances in other fields with major health benefits, such as improved provision of water supplies, sewerage, and household sanitation.

Around 1950, for every 1,000 children who were born an estimated 134 would die before their first birthday. That number, 134 deaths under 1 year per 1,000 births, is called the infant mortality rate, or IMR. It signifies the proportion of newborns that won't survive to their first birthday, in this case, 13.4 percent (134/1,000). It is heartening that the IMR has been coming down sharply to an estimated 37 per 1,000 today. But we must remember this means 37 of every 1,000 newborns (3.7 percent) still do not survive to their first birthday, dying of malaria, pneumonia, diarrheal disease, or other preventable diseases of infants. These are tragedies that continue to occur around the world, with around 5 million children, almost all in developing countries, succumbing by age 1, and around 6 million dying each year under the age of 5. Still, the drop from 134 to 37 in infant mortality is a tremendous accomplishment of economic development and public health systems (including improved medical care, greater food security, greater access to safe water and sanitation, and other contributors to improved health). The decline in mortality rates at all ages has improved the quality of life and certainly eliminated a lot of the tragedy and anguish that was part of humanity's existence up until the improvements in public health and medical care in the past century.

With more children surviving and with health improving at older ages as well, the good news is that our life expectancy is also rising considerably. A good measure of this is life expectancy at birth. Life expectancy measures the average life span, taking into account the risks of death at each age. In the middle of the last century, in the five-year period from 1950 to 1955, the average life expectancy for the entire world population was around forty-seven years. Today, the estimated life expectancy at birth is roughly seventy-one years, and it is as high as eighty years in high-income countries. This tremendous increase in longevity is another benefit of economic growth and material progress and exemplifies the broad trend of improvement being achieved in most parts of the world.

The first major economic lesson of recent history is that the first pillar of sustainable development—prosperity achieved through economic growth—is achievable by rapid advances in health technologies, including medical advances such as antibiotics, vaccinations, diagnostics, and vast improvements in surgery, as well as advances in other fields with major health benefits, such as improved provision of water supplies, sewerage, and household sanitation.

Around 1950, for every 1,000 children who were born an estimated 134 would die before their first birthday. That number, 134 deaths under 1 year per 1,000 births, is called the infant mortality rate, or IMR. It signifies the proportion of newborns that won't survive to their first birthday, in this case, 13.4 percent (134/1,000). It is heartening that the IMR has been coming down sharply to an estimated 37 per 1,000 today. But we must remember this means 37 of every 1,000 newborns (3.7 percent) still do not survive to their first birthday, dying of malaria, pneumonia, diarrheal disease, or other preventable diseases of infants. These are tragedies that continue to occur around the world, with around 5 million children, almost all in developing countries, succumbing by age 1, and around 6 million dying each year under the age of 5. Still, the drop from 134 to 37 in infant mortality is a tremendous accomplishment of economic development and public health systems (including improved medical care, greater food security, greater access to safe water and sanitation, and other contributors to improved health). The decline in mortality rates at all ages has improved the quality of life and certainly eliminated a lot of the tragedy and anguish that was part of humanity's existence up until the improvements in public health and medical care in the past century.

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The first major economic lesson of recent history is that the first pillar of sustainable development—prosperity achieved through economic growth—is achievable

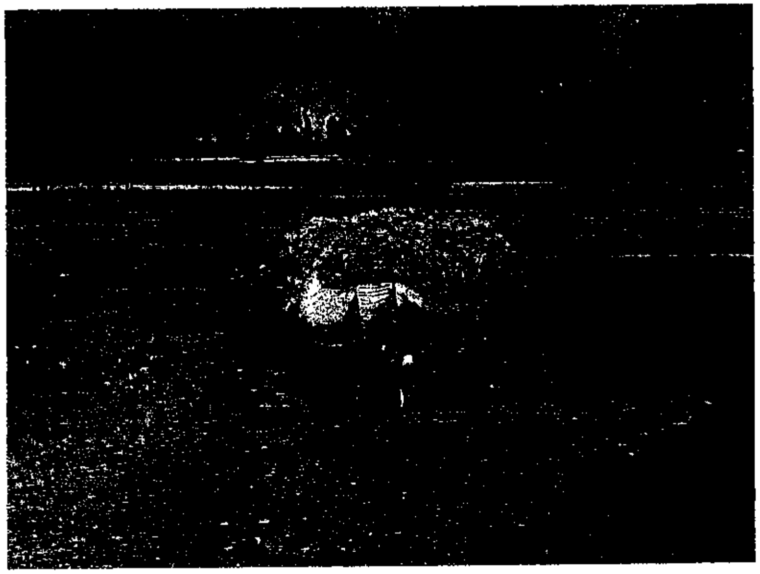
on a large scale, and indeed is being achieved across large parts of the planet. Most parts of the world have been benefiting from a rise in GDP per person. That increase in GDP per person has been accompanied by several structural changes in society: from rural life as peasant farmers to urban life with employment in industry or services. There are fewer tragic deaths of young children and greater health and longevity for most of us, with life expectancy now several decades higher than what it was in the middle of the twentieth century.

China's experience, repeated somewhat less dramatically in many other countries, shows that high per capita incomes need not be the preserve of a small, narrow part of the world (covering the United States, Canada, Europe, Japan, Australia, and New Zealand, but very few other places) as it was until recently, but can in fact be achieved almost everywhere. However, as we noted briefly in the case of China, even rapid economic growth is not sufficient to ensure wellbeing. We must ensure that the economic growth is inclusive and does not leave millions of people behind. We must ensure that economic growth is environmentally sustainable, so that progress does not undermine the Earth's life-support systems of high biodiversity, soil productivity, a safe climate, and productive oceans. Unless we combine economic growth with social inclusion and environmental sustainability, the economic gains are likely to be short-lived, as they will be followed by social instability and a rising frequency of environmental catastrophes.

III. Continuing Poverty in the Midst of Plenty

In many ways we already live in a world of plenty. Economic growth has produced incredible wealth, and most parts of the world have escaped from extreme economic hardship. Countries like China that were once very poor are now middle-income countries. Yet despite these advances, parts of the world remain stuck in extreme poverty. Perhaps the most urgent economic challenge on the planet is to help populations still living at the edge of survival to achieve economic growth and escape from poverty.

What is extreme poverty today? Figure 1.7 shows a smallholder farmer living in northern Ethiopia, in the Koraro village of Tigray Province, the site of a

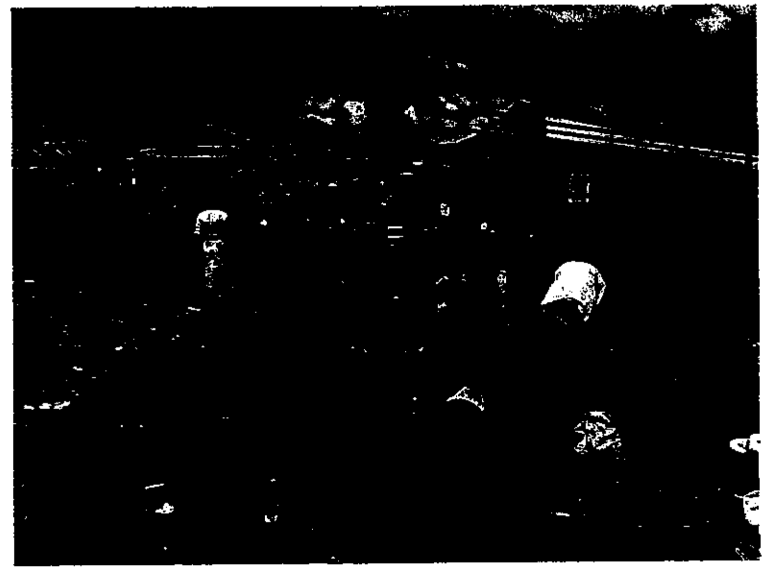


1.7 Smallholder farming life in Northern Ethiopia

Photo courtesy of John Hubers.

Millennium Village. The farmer is hidden behind a great bale of grain carried by his donkey. There is no modern transport, no electricity grid. The land is parched. This is a dry region of poor farm households eking out a living and trying to ensure enough annual food production to feed themselves and their families. If they are lucky, they may produce a small surplus of grain to bring to market for a bit of cash income.

Figure 1.8 shows a street in Nairobi's Kibera slum, the urban face of extreme poverty. Hundreds of millions of people live in urban slums around the world. Often urban poverty abuts right up against great urban wealth. Looking closely, we see an unpaved muddy road that is not really passable by vehicles. As the photo shows, people living in this slum may see power lines overhead, but they may be



1.8 Kibera slum, Nairobi, Kenya

"Scenes from the Kibera slum in Nairobi," Karl Mueller, Flickr, CC BY 2.0.

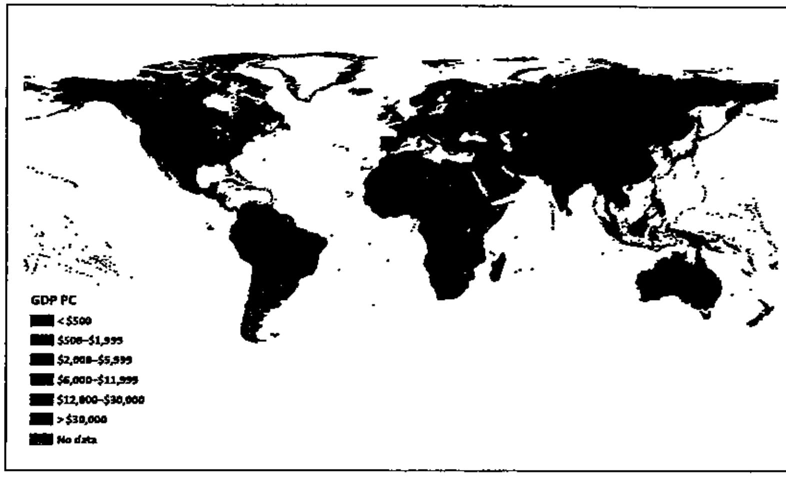
too poor to be connected to the grid. These people also probably get by without modern sewerage or household sanitation, often having to defecate in open places. They are perhaps buying their water from a water truck, because there is no piped water to individual households and perhaps not even a shared public water stand for the community.

In short, even though these slum dwellers are living in an urban area of several million people, they are, like their counterparts in northern Ethiopia, mostly unable to secure basic needs, to access emergency health care, electricity, adequate nutrition, clean cookstoves, safe water, and sanitation. They may barely eke out a living in informal employment. They may earn just enough to buy a minimum of food, water, clothing, and shelter.

Extreme poverty is a multidimensional concept. Poverty is typically described as the lack of adequate income, but extreme poverty should be understood in more general terms as the inability to meet basic human needs for food, water, sanitation, safe energy, education, and a livelihood. Extreme poverty means lacking modern energy for safe cooking, such as natural gas, with the household instead relying on wood-burning stoves that cause chronically smoke-filled homes and subsequent respiratory diseases in the children. Extreme poverty often means that households cannot secure decent schooling for their children. There may be no school nearby, or no qualified teacher, or a school that charges tuition beyond the household's income.

People living in extreme poverty are, simply put, people who cannot meet their basic needs. Life is a daily struggle for dignity, and even for survival. While the numbers living in extreme poverty around the world have been declining, and the proportion of the world population living in extreme poverty has been shrinking even faster in recent decades, the number of people still struggling in extreme poverty is staggering. Depending on one's estimate and the exact definitions used, more than 1 billion people, and perhaps as many as 2.5 billion people, can be categorized as living in extreme poverty. It is probably accurate to say, and shocking to think about, that around one billion people struggle each day for their mere survival. They worry about whether they will they have enough to eat; they worry that unsafe water will cause a life-threatening disease; they worry that a mosquito bite transmitting malaria will take the life of their child, because they cannot afford the 80-cent dose of medicine needed to treat the infection.

This struggle for survival occurs in both rural and urban areas. It is still predominantly rural (perhaps in a ratio of 60:40), but it is increasingly taking on an urban face in the world's slums. Where is this extreme poverty? One shortcut is to look at the GDP per person around the world. As a general principle, economies with low GDP per capita also tend to be places where households live in extreme poverty. Figure 1.9 is a color-coded map of the world in which the colors denote the GDP per capita measured in purchasing power–adjusted terms (in 2011 prices). The map shows the huge variation in per capita GDP around the world. The countries in blue have GDP per capita above $30,000. There are not too many of them: the United States and Canada, most of western Europe, Japan,



1.9 GDP per capita (2011 prices, PPP)

Source: World Bank. 2014. "World Development Indicators."

Australia, and a few small, oil-rich states in the Middle East. By and large, extreme poverty has been completely eliminated from those countries.

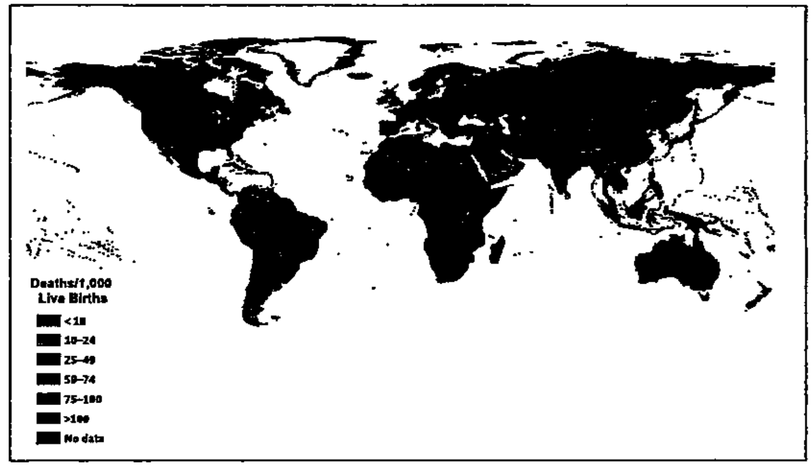
Next come the countries colored lighter blue, with GDP per capita between $12,000 and $30,000, still high by world standards. These include Israel, Korea, New Zealand, Russia, and several countries in central Europe. Contrast that with the red parts of the world. These are the places of very low GDP per capita, less than $2,000 in PPP terms, and also the highest concentration of populations living in extreme poverty. It is clear from this map that the poorest countries in the world are concentrated in tropical sub-Saharan Africa, those countries lying south of North Africa and north of the southern tip of Africa. Many of these tropical African countries are very poor, with around half of the population living in extreme poverty. The next poorest region, also home to vast numbers of people living in extreme poverty, is South Asia—including India, Pakistan, Nepal, and Bangladesh. Even though the GDP per capita is typically higher in South Asia than in tropical Africa, the South Asian economies have vast populations and many people living in extreme poverty. In both Africa and South Asia, the proportions of households living in extreme poverty have been falling, but there is still a huge challenge in ending extreme poverty, a subject we will consider in detail in a later chapter.

Notice as well a few other places with pockets of poverty, such as landlocked Bolivia in South America and landlocked countries in central Asia such as Mongolia. These are countries where poverty is high and geography is difficult. We shall see that being landlocked makes economic growth more difficult. Economic growth often depends on international trade, but international trade is very hard for countries that are hundreds or even over a thousand kilometers from a port, with the port possibly in another country to boot. (Coastal countries with ports are often relatively hostile to their landlocked next-door neighbors, since they have sometimes fought wars over access to the sea.)

Figure 1.10 maps another aspect of extreme poverty: the mortality rate of infants (IMR) (deaths of children under 1 year per 1,000 births), shown for data from 2013. Infants living in extreme poverty face a burden of disease and much higher risks of mortality than non-poor children. Once again, where is the concentration of child mortality? Tropical Africa and parts of South Asia are again the epicenters of the global challenge.

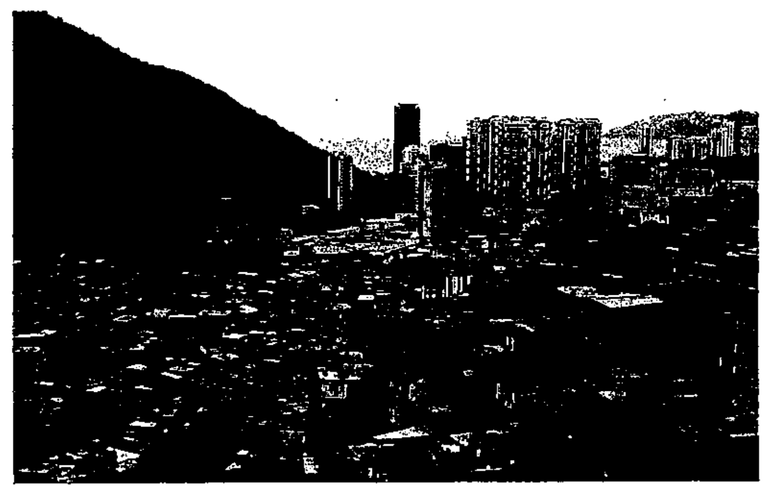
Even in countries where the vast majority of the population has escaped from extreme poverty, there can still be very significant pockets of poverty. Brazil is a case in point. Most of the poor in Brazil are able to meet their basic needs (and hence should not be described as living in "extreme" poverty), but they are still vastly poorer and vastly disadvantaged compared with their richer urban neighbors. Sometimes the starkness of the divisions of income and social status are right in front of our eyes, and the eyes of the poor. Take, for example, the view of Rio de Janeiro in figure 1.11, with its contrast of favelas (slums) and modern high-rises.

As always with sustainable development, there is hope for the extreme poor and for those living in relative poverty as in Rio. There are practical approaches, things that can be done, to help even the poorest of the poor to meet their basic needs and to help them succeed in the daily struggle for survival. We will be examining such approaches in detail later in the book. One that I find most exciting



1.10 Global infant mortality rates (deaths under 1 per 1,000 births)

Source: World Bank. 2014. "World Development Indicators."



1.11 Wealth and poverty in Rio de Janeiro

"Rocinha_68860004," matteo0702, Flickr, CC BY 2.0.

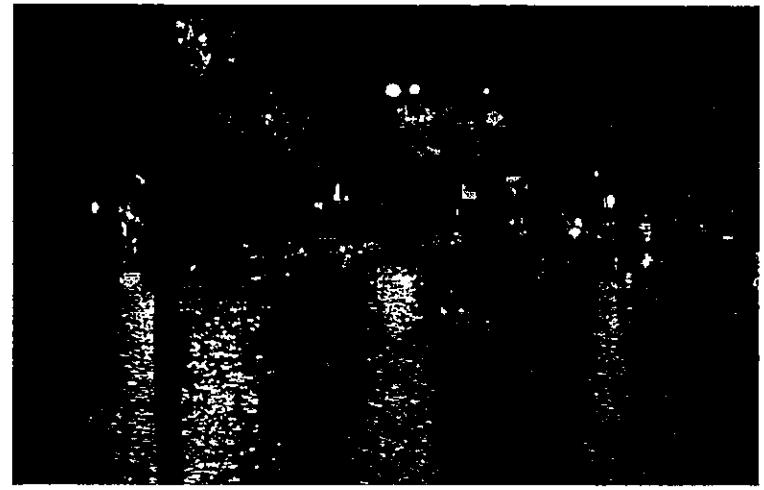
is the idea of Community Health Workers (CHWs) in poor villages and slums who bring health care to people who otherwise would be disconnected from the health system. We will see how modern technologies have made the CHWs especially effective in recent years.

We have noted that the extent of poverty has a strong geographical pattern. The highest proportions of extreme poverty are in tropical Africa and South Asia. We will study some of the reasons for this geographical pattern. It is not a coincidence. Geography shapes many things about an economy, including the productivity of farms, the burdens of infectious diseases, the costs of trade, and the access to energy resources. We will examine such geographical factors later in the book. Fortunately, geography is not destiny. Even if a particular region is vulnerable to specific diseases (such as malaria), modern technologies offer modern solutions. Geographical reasoning helps us to identify the high-return investments that can help the poorest of the poor to escape from poverty.

IV. Global Environmental Threats Caused by Economic Development

One of the most important messages of the field of sustainable development is that humanity has become a serious threat to its own future wellbeing, and perhaps even its survival, as the result of unprecedented human-caused harm to the natural environment. Gross world product per person, now at $12,000 per person, combined with a global population of 7.2 billion people, means that the annual world output is at least 100 times larger than at the start of the Industrial Revolution. That 240-fold increase in world output (or even a thousandfold increase on particular dimensions of economic activity) results in multiple kinds of damage to the planet. Large-scale economic activity is changing the Earth's climate, water cycle, nitrogen cycle, and even its ocean chemistry. Humanity is using so much land that it is literally crowding other species off the planet, driving them to extinction.

This crisis is felt by rich and poor alike. In late October 2012, police cars floated down the street in Manhattan during Superstorm Sandy, one of the strongest storms to hit the Eastern Seaboard in modern times (see figure 1.12). Even if



1.12 Flooding in Manhattan during Superstorm Sandy, October 2012

"Hurricane Sandy Flooding Avenue C 2012," David Shankbone, Wikimedia Commons, CC BY 3.0.

scientists can't determine whether the storm's remarkable ferocity was due in part to human-induced climate change, they can determine that human-induced climate change greatly amplified the *impact* of the storm. As of 2012, the ocean level off the Eastern Seaboard of the United States was roughly one-third of a meter higher than a century earlier, the result of global warming causing a rise in ocean levels around the world. This higher sea level greatly exacerbated the flooding associated with the superstorm.

Superstorm Sandy wasn't the only climate-related shock to the United States that year. Earlier in the year, U.S. crops suffered major losses as the result of a mega-drought and heat wave in the Midwest and western grain-growing regions (see figure 1.13). Drought conditions have continued to burden some parts of the U.S. West since then, with California in an extreme drought as of 2014.

Halfway around the world from New York City, also during 2012, Beijing experienced massive flooding that followed especially heavy rains. Bangkok

1.13 Corn fields in Iowa drought (2012)

"Iowa County Drought," CindyH Photography, Flickr,

experienced astounding floods in October 2011 (see figure 1.14). Indonesia experienced heavy flooding in early 2014, while Australia suffered another devastating heat wave. All of these events were huge setbacks for both the local and global economy, with loss of life, massive loss of property, billions or even tens of billions of dollars of damage, and disruptions to the global economy. The floods in Bangkok, for example, flooded automobile parts suppliers, shutting down assembly lines in other parts of the world when the parts failed to arrive.

The particular disasters are varied, but it is clear that one broad category—climate-related catastrophes—is rising in number and severity. One major class of climate shocks is known as "hydrometeorological disasters." These are water- and weather-related disasters, including heavy precipitation, extreme storms, high-intensity hurricanes and typhoons, and storm-related flood surges such as those that swept over Manhattan, Beijing, and Bangkok. Massive droughts

1.14 Bangkok floods (2011)

"USS Mustin provides post-flood relief in Thailand," Jennifer Villalovos, U.S. Navy.

cause deadly famines in Africa, crop failures in the United States, and a dramatic increase in forest fires in the United States, Europe, Russia, Indonesia, Australia, and other parts of the world. Other climate-related catastrophes include the spread of diseases and pests that threaten food supplies and the survival of other species.

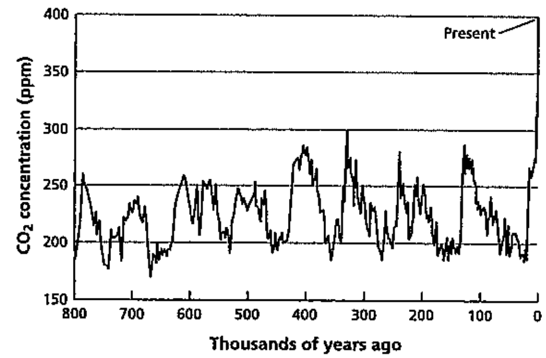
The frequency and severity of these threats have risen dramatically and are likely to increase still further. Indeed, the reshaping of the Earth's physical systems—including climate, chemistry, and biology—is so dramatic that scientists have given our age a new scientific name: the *Anthropocene.* This is a new word that comes from its Greek roots: *anthropos,* meaning humankind, and *cene,* meaning epoch or period of Earth's history. The Anthropocene is the era—our era—in which humanity, through the massive impacts of the world economy, is creating major disruptions of Earth's physical and biological systems.

In the language of the scientists, human-induced changes are "driving" the Earth's physical and biological changes. To a layperson, the word "driving" might suggest that somebody is in control. That's not what the scientists mean. They mean that humanity is *causing* changes that are large, serious, and highly disruptive, with most of humanity, including most political leaders, having little scientific understanding of the dangers ahead.

The study of sustainable development requires a deep understanding of these human-induced changes, most importantly so we can change course and protect ourselves and future generations. One of the main drivers of change is humanity's massive use of coal, oil, and natural gas, the primary energy sources we call fossil fuels. When we burn coal, oil, and gas to move vehicles, heat buildings, transform minerals into steel and cement, and produce electricity, the combustion process produces CO_2 that is emitted into the atmosphere. The rising concentration of CO_2 in the atmosphere is the main, though not the only, source of human-induced climate change.

Figure 1.15 tells a remarkable story. It depicts the fluctuating levels of CO_2 in the atmosphere over the past 800,000 years. The distant past is on the left-hand side of the figure; the present is all the way to the right. The vertical axis measures CO_2 in the atmosphere. The measurement unit is the number of molecules of CO_2 for every 1 million molecules in the atmosphere. As of today, there are around 400 CO_2 molecules per million, or 400 parts per million (ppm). That doesn't seem like very much: just 0.04 percent. Yet even small changes in this concentration have a big effect on the climate.

Start on the left-hand side of the graph. 800,000 years ago, the CO_2 concentration was around 190 ppm. We see that it rose to peak around 260 ppm before falling to a low of around 170 ppm around 740,000 years ago. In general, CO_2 rises and falls like the teeth of a saw. These fluctuations are natural. They are "driven" (i.e., caused) mainly by slight changes in the Earth's orbital patterns around the sun; changes involving the shape of the orbit; slight variations in the Earth's distance to the sun; and the fluctuations in the tilt of the Earth relative to the plane of the Earth's orbit, causing slight changes in the pattern of the seasons. When the orbit changes slightly in ways that tend to heat the Earth, a feedback process tends to cause the release of CO_2 dissolved in the oceans, which then escapes into



1.15 CO_2 in the atmosphere over the past 800,000 years

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Note: Ice core data before 1958; Mauna Loa data after 1958.

the atmosphere (just as CO_2 gas bubbles escape if one heats a pot filled with soda water). In turn, as the CO_2 rises in the atmosphere, the result is to warm the planet even more. We say that the increase in CO_2 is a "positive feedback." The change in the orbit slightly warms the planet; that releases CO_2 into the atmosphere, which in turn causes a further rise in temperature.

Scientists have shown that whenever the atmospheric concentration of CO_2 was high, the Earth tended to be warm (mostly because of the CO_2). Whenever CO_2 was low (because the atmospheric CO_2 was reabsorbed into the ocean), the Earth tended to be cold. Indeed, in the low phases of the natural CO_2 cycle, the Earth was actually cold enough to produce an ice age, with much of the Northern Hemisphere covered by a thick sheet of ice. By relating the concentration of CO_2 to the Earth's temperature (determined by other means), scientists have found a systematic relationship of high CO_2 and high Earth temperatures.

The far right-hand side of the graph shows that in the last blink of an eye in geological time, really in the past 150 years, the concentration of CO_2 has shot up like a vertical rocket. This is not because of natural changes in the Earth's orbit. This time, the rise in CO_2 has a human cause: the burning of fossil fuels. Notice the key and alarming point: humanity has pushed the level of CO_2 in the atmosphere to 400 ppm, higher than at any time in the past 800,000 years. Indeed, the last time the CO_2 concentration was so high was 3 million years ago, literally off the chart! And when the CO_2 level was that high 3 million years ago, the Earth was vastly warmer than today.

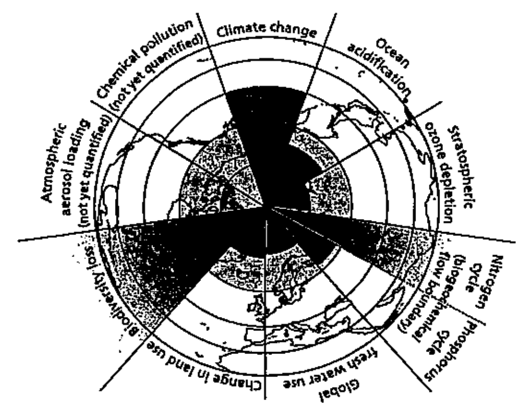
Why worry, you might wonder. The reason is that all of our civilization—the location of our cities, the crops we grow, and the technologies that run our industry—is based on a climate pattern that will soon disappear from the planet. The Earth will become much warmer than it has been during the entire period of civilization; the sea level will be come much higher, threatening coastal cities and low-lying countries; the crops that feed humanity will suffer many devastating harvest failures as a result of high temperatures, new kinds of pests, droughts, floods, losses of biodiversity (such as pollinating species), and other calamities. We will study these threats in detail.

A few years ago, a group of scientists noted that what humanity is doing, including producing carbon emissions but also much more, is disrupting not just the climate but several of Earth's natural systems. These include the depletion of freshwater sources (such as underground aquifers); the pollution from heavy use of chemical fertilizers (applied in order to improve crop productivity); the change in ocean chemistry, mainly the increasing acidity of the ocean resulting from atmospheric CO_2 dissolving into ocean water; the clearing of forests to create new pastureland and farmland; and particulate pollution caused by many industrial processes, especially those involving the combustion of coal. All pose deep threats to the Earth and the wellbeing of humanity. These scientists argued that the extent of the damage is so large that humanity is leaving the "safe operating conditions" for the planet (Rockström et al. 2009). It is as if we are driving the car right off the road and into the ditch, or worse, right over the cliff.

The scientists argued that it is urgent to identify the safe operating limits for the planet or, put another way, to define the "planetary boundaries" beyond which humanity should not venture. For example, pushing CO_2 to 400 ppm might be dangerous, but pushing CO_2 to 450 ppm (through continued heavy use of fossil

fuels) could be reckless. Depleting some groundwater could be inconvenient. Depleting major aquifers could be devastating. Raising the ocean's acidity slightly could be bad for shellfish. Raising the ocean's acidity dramatically could kill off a massive amount of marine life, including the species of fish and shellfish that humanity consumes as a vital part of our food supply.

Figure 1.16 offers the scientists' visualization of these planetary boundaries (Rockström et al. 2009, 472). Starting at 12 o'clock and moving clockwise around the circle we see the ten major planetary boundaries that humanity is in danger of exceeding, starting with climate change, ocean acidification, and so forth. The red shaded area shows the scientists' assessment of how close the world is to exceeding each of these boundaries. In the case of nitrogen flux (from fertilizer use) and biodiversity loss, the entire wedge of the circle is red. We have already exceeded these planetary boundaries. For other threats, we are still some way from the boundaries, although the red-shaded portions of each slice of the pie



1.16 Planetary boundaries

Reprinted by permission from Macmillan Publishers Ltd: Nature, *Rockström, Johan, Will Steffen, Kevin Noone, Åsa Persson, F. Stuart Chapin, Eric F. Lambin, Timothy M. Lenton et al. "A Safe Operating Space for Humanity," copyright 2009.*

are increasing rapidly. During the twenty-first century, the entire circle will likely turn red unless there is a fundamental change of strategy. Put another way, humanity will exceed the safe operating limits unless the world adopts a strategy to achieve sustainable development.

V. Pathways to Sustainable Development

The first part of sustainable development—the analytical part—is to understand the interlinkages of the economy, society, environment, and politics. The second part of sustainable development—the normative part—is to do something about the dangers we face, to implement SDGs, and to achieve them! Our overarching goal should be to find a global path, made up of local and national paths, in which the world promotes inclusive and sustainable economic development, thereby combining the economic, social, and environmental objectives. This can only be accomplished if a fourth objective—good governance of both governments and businesses—is also achieved. Good governance, I shall repeatedly emphasize, means many things. It applies not only to government but also to business. It means that both the public sector (government) and the private sector (business) operate according to the rule of law, with accountability, transparency, responsiveness to the needs of stakeholders, and with the active engagement of the public on critical issues such as land use, pollution, and the fairness and honesty of political and business practices.

In the coming chapters, I will constantly refer to a comparison. On the one hand, we will consider the implications of humanity continuing on the current course. For example, suppose that the world economy continues as today to be run mainly on fossil fuels, so that the CO_2 concentration in the atmosphere continues to rise rapidly. Or suppose that farmers continue to overuse groundwater so much that the aquifers are depleted. These scenarios will be called *business as usual*, or BAU for short. Such scenarios will be compared with a dramatic change of course for humanity, one in which the world quickly adopts new technologies (e.g., solar power to replace coal-fired electricity generation

or more efficient water use to avoid depleting the aquifers). The alternative path, one that aims not only for economic growth but also for social inclusion and environmental sustainability, will be called the *sustainable development* path, or SD for short.

We will examine and contrast the BAU and SD trajectories. If we continue with BAU, what would happen? Certainly there would continue to be many kinds of progress. Science and technology won't stand still. The poor will benefit from advances in ICTs, such as access to higher education through free, online learning. Poverty would continue to fall in many places. The rich might continue to become richer for another decade or two. Yet eventually, the negative consequences of rising inequality and rising environmental destruction will come to dominate the positive tendencies. Progress will peak. Calamities, both social and environmental, will start to dominate. More than 200 years of progress could be choked off, and even sacrificed to war.

What about SDGs? Can we find alternatives to fossil fuels, groundwater, pasturelands, and the like, to meet human needs without destroying the physical environment? Some of the key solutions are likely to be more expensive in the short term, such as buildings specially designed to use less energy for heating through better design, insulation, materials, and overall systems strategy; or electric vehicles with battery power that are still expensive compared with normal gas-guzzling internal combustion engines. Some fear that we can't afford the SD path; that the SD path might "save" humanity at the cost of ending economic progress; and that SDGs are therefore unrealistic, even impossible to achieve. A major task of this book is to examine this claim. Without giving away the entire plot, I'll say at the outset that if we are clever and apply ourselves to the study and design of new sustainable business practices and technologies, sustainable development is both feasible and affordable. Indeed, it is business as usual that eventually would impose the truly devastating costs.

The essence of sustainable development in practice is *scientifically and morally based problem solving*. We indeed have a lot of problems. We have continued life-threatening poverty in the midst of plenty. We have built up inequalities of wealth and poverty, and we have deployed technology systems that are now crossing planetary boundaries. We are going to need a coordinated global effort in a focused and relatively short period of time, a matter of decades rather than centuries, to move from the BAU to the SD trajectory. In order to accomplish the SDGs, every part of the world will have to be involved in problem solving, in brainstorming, and in determining new and creative ways to ensure inclusive and sustainable growth. This book aims to contribute to that problem solving. We will describe the challenges, identify and discuss the new SDGs, and determine how those SDGs can in fact be achieved.