from Lester R. Brown, *Eco-Economy: Building an Economy for the Earth*
(W. W. Norton & Co., NY: 2001)

Eco-Economy

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The Economy and the Earth

In 1543, Polish astronomer Nicolaus Copernicus published "On the Revolutions of the Celestial Spheres," in which he challenged the view that the Sun revolved around the earth, arguing instead that the earth revolved around the Sun. With his new model of the solar system, he began a wide-ranging debate among scientists, theologians, and others. His alternative to the earlier Ptolemaic model, which had the earth at the center of the universe, led to a revolution in thinking, to a new worldview.[1]

Today we need a similar shift in our worldview, in how we think about the relationship between the earth and the economy. The issue now is not which celestial sphere revolves around the other but whether the environment is part of the economy or the economy is part of the environment. Economists see the environment as a subset of the economy. Ecologists, on the other hand, see the economy as a subset of the environment.

Like Ptolemy's view of the solar system, the economists' view is confusing efforts to understand our modern world. It has created an economy that is out of sync with the ecosystem on which it depends.

Economic theory and economic indicators do not explain how

the economy is disrupting and destroying the earth's natural systems. Economic theory does not explain why Arctic Sea ice is melting. It does not explain why grasslands are turning into desert in northwestern China, why coral reefs are dying in the South Pacific, or why the Newfoundland cod fishery collapsed. Nor does it explain why we are in the early stages of the greatest extinction of plants and animals since the dinosaurs disappeared 65 million years ago. Yet economics is essential to measuring the cost to society of these excesses.

Evidence that the economy is in conflict with the earth's natural systems can be seen in the daily news reports of collapsing fisheries, shrinking forests, eroding soils, deteriorating rangelands, expanding deserts, rising carbon dioxide (CO_2) levels, falling water tables, rising temperatures, more destructive storms, melting glaciers, rising sea level, dying coral reefs, and disappearing species. These trends, which mark an increasingly stressed relationship between the economy and the earth's ecosystem, are taking a growing economic toll. At some point, this could overwhelm the worldwide forces of progress, leading to economic decline. The challenge for our generation is to reverse these trends before environmental deterioration leads to long-term economic decline, as it did for so many earlier civilizations.

These increasingly visible trends indicate that if the operation of the subsystem, the economy, is not compatible with the behavior of the larger system—the earth's ecosystem—both will eventually suffer. The larger the economy becomes relative to the ecosystem, and the more it presses against the earth's natural limits, the more destructive this incompatibility will be.

An environmentally sustainable economy—an eco-economy—requires that the principles of ecology establish the framework for the formulation of economic policy and that economists and ecologists work together to fashion the new economy. Ecologists understand that all economic activity, indeed all life, depends on the earth's ecosystem—the complex of individual species living together, interacting with each other and their physical habitat. These millions of species exist in an intricate balance, woven together by food chains, nutrient cycles, the hydrological cycle, and the climate system. Economists know how to translate goals into policy. Economists and ecologists working together can design and build an eco-economy, one that can sustain progress.

Just as recognition that the earth was not the center of the solar system set the stage for advances in astronomy, physics, and related sciences, so will recognition that the economy is not the center of our world create the conditions to sustain economic progress and improve the human condition. After Copernicus outlined his revolutionary theory, there were two very different worldviews. Those who retained the Ptolemaic view of the world saw one world, and those who accepted the Copernican view saw a quite different one. The same is true today of the disparate worldviews of economists and ecologists.

These differences between ecology and economics are fundamental. For example, ecologists worry about limits, while economists tend not to recognize any such constraints. Ecologists, taking their cue from nature, think in terms of cycles, while economists are more likely to think linearly, or curvilinearly. Economists have a great faith in the market, while ecologists often fail to appreciate the market adequately.

The gap between economists and ecologists in their perception of the world as the new century begins could not be wider. Economists look at the unprecedented growth of the global economy and of international trade and investment and see a promising future with more of the same. They note with justifiable pride that the global economy has expanded sevenfold since 1950, raising output from $6 trillion of goods and services to $43 trillion in 2000, boosting living standards to levels not dreamed of before. Ecologists look at this same growth and realize that it is the product of burning vast quantities of artificially cheap fossil fuels, a process that is destabilizing the climate. They look ahead and see more intense heat waves, more destructive storms, melting ice caps, and a rising sea level that will shrink the land area even as population continues to grow. While economists see booming economic indicators, ecologists see an economy that is altering the climate with consequences that no one can foresee.[2]

As the new century gets under way, economists look at grain markets and see the lowest grain prices in two decades—a sure sign that production capacity is outrunning effective demand, that supply constraints are not likely to be an issue for the foreseeable future. Ecologists, meanwhile, see water tables falling in key food-producing countries, and know that 480 million of the world's 6.1 billion people are being fed with grain produced by overpumping

aquifers. They are worried about the effect of eventual aquifer depletion on food production.[3]

Economists rely on the market to guide their decisionmaking. They respect the market because it can allocate resources with an efficiency that a central planner can never match (as the Soviets learned at great expense). Ecologists view the market with less reverence because they see a market that is not telling the truth. For example, when buying a gallon of gasoline, customers in effect pay to get the oil out of the ground, refine it into gasoline, and deliver it to the local service station. But they do not pay the health care costs of treating respiratory illness from air pollution or the costs of climate disruption.

Ecologists see the record economic growth of recent decades, but they also see an economy that is increasingly in conflict with its support systems, one that is fast depleting the earth's natural capital, moving the global economy onto an environmental path that will inevitably lead to economic decline. They see the need for a wholesale restructuring of the economy so that it meshes with the ecosystem. They know that a stable relationship between the economy and the earth's ecosystem is essential if economic progress is to be sustained.

We have created an economy that cannot sustain economic progress, an economy that cannot take us where we want to go. Just as Copernicus had to formulate a new astronomical worldview after several decades of celestial observations and mathematical calculations, we too must formulate a new economic worldview based on several decades of environmental observations and analyses.

Although the idea that economics must be integrated into ecology may seem radical to many, evidence is mounting that it is the only approach that reflects reality. When observations no longer support theory, it is time to change the theory—what science historian Thomas Kuhn calls a paradigm shift. If the economy is a subset of the earth's ecosystem, as this book contends, the only formulation of economic policy that will succeed is one that respects the principles of ecology.[4]

The good news is that economists are becoming more ecologically aware, recognizing the inherent dependence of the economy on the earth's ecosystem. For example, some 2,500 economists—including eight Nobel laureates—have endorsed the introduction

of a carbon tax to stabilize climate. More and more economists are looking for ways to get the market to tell the ecological truth. This spreading awareness is evident in the rapid growth of the International Society of Ecological Economics, which has 1,200 members and chapters in Australia/New Zealand, Brazil, Canada, India, Russia, China, and throughout Europe. Its goal is to integrate the thinking of ecologists and economists into a transdiscipline aimed at building a sustainable world.[5]

Economy Self-Destructing

The economic indicators for the last half-century show remarkable progress. As noted earlier, the economy expanded sevenfold between 1950 and 2000. International trade grew even more rapidly. The Dow Jones Index, a widely used indicator of the value of stocks traded on the New York Stock Exchange, climbed from 3,000 in 1990 to 11,000 in 2000. It was difficult not to be bullish about the long-term economic prospect as the new century began.[6]

Difficult, that is, unless you look at the ecological indicators. Here, virtually every global indicator was headed in the wrong direction. The economic policies that have yielded the extraordinary growth in the world economy are the same ones that are destroying its support systems. By any conceivable ecological yardstick, these are failed policies. Mismanagement is destroying forests, rangelands, fisheries, and croplands—the four ecosystems that supply our food and, except for minerals, all our raw materials as well. Although many of us live in a high-tech urbanized society, we are as dependent on the earth's natural systems as our hunter-gatherer forebears were.

To put ecosystems in economic terms, a natural system, such as a fishery, functions like an endowment. The interest income from an endowment will continue in perpetuity as long as the endowment is maintained. If the endowment is drawn down, income declines. If the endowment is eventually depleted, the interest income disappears. And so it is with natural systems. If the sustainable yield of a fishery is exceeded, fish stocks begin to shrink. Eventually stocks are depleted and the fishery collapses. The cash flow from this endowment disappears as well.

As we begin the twenty-first century, our economy is slowly destroying its support systems, consuming its endowment of natural capital. Demands of the expanding economy, *as now structured*,

are surpassing the sustainable yield of ecosystems. Easily a third of the world's cropland is losing topsoil at a rate that is undermining its long-term productivity. Fully 50 percent of the world's rangeland is overgrazed and deteriorating into desert. The world's forests have shrunk by about half since the dawn of agriculture and are still shrinking. Two thirds of oceanic fisheries are now being fished at or beyond their capacity; overfishing is now the rule, not the exception. And overpumping of underground water is common in key food-producing regions.[7]

Over large areas of the world, the loss of topsoil from wind and water erosion now exceeds the natural formation of new soil, gradually draining the land of its fertility. In an effort to curb this, the United States is retiring highly erodible cropland that was earlier plowed in overly enthusiastic efforts to expand food production. This process began in 1985 with the Conservation Reserve Program that paid farmers to retire 15 million hectares, roughly one tenth of U.S. cropland, converting it back to grassland or forest before it became wasteland.[8]

In countries that lack such programs, farmers are being forced to abandon highly erodible land that has lost much of its topsoil. Nigeria is losing over 500 square kilometers of productive land to desert each year. In Kazakhstan, site of the 1950s Soviet Virgin Lands project, half the cropland has been abandoned since 1980 as soil erosion lowered its productivity. This has dropped Kazakhstan's wheat harvest from roughly 13 million tons in 1980 to 8 million tons in 2000—an economic loss of $900 million per year.[9]

The rangelands that supply much of the world's animal protein are also under excessive pressure. As human populations grow, so do livestock numbers. With 180 million people worldwide now trying to make a living raising 3.3 billion cattle, sheep, and goats, grasslands are simply collapsing under the demand. As a result of overstocking, grasslands are now deteriorating in much of Africa, the Middle East, Central Asia, the northern part of the Indian subcontinent, and much of northwestern China. Overgrazing is now the principal cause of desertification, the conversion of productive land into desert. In Africa, the annual loss of livestock production from the cumulative degradation of rangeland is estimated at $7 billion, a sum almost equal to the gross domestic product of Ethiopia.[10]

In China, the combination of overplowing and overgrazing to satisfy rapidly expanding food needs is creating a dust bowl reminiscent of the U.S. Dust Bowl of the 1930s—but much larger. In a desperate effort to maintain grain self-sufficiency, China has plowed large areas of the northwest, much of it land that is highly erodible and should never have been plowed.[11]

As the country's demand for livestock products—meat, leather, and wool—has climbed, so have the numbers of livestock, far exceeding those of the United States, a country with comparable grazing capacity. In addition to the direct damage from overplowing and overgrazing, the northern half of China is literally drying out as aquifers are depleted by overpumping.[12]

These trends are converging to form some of the largest dust storms ever recorded. The huge dust plumes, traveling eastward, affect the cities of northeast China—blotting out the sun and reducing visibility. Eastward-moving winds also carry soil from China's northwest to the Korean Peninsula and Japan, where people regularly complain about the dust clouds that filter out the sunlight and blanket everything with dust. Unless China can reverse the overplowing and overgrazing trends that are creating the dust bowl, these trends could spur massive migration into the already crowded cities of the northeast and undermine the country's economic future.[13]

The world is also running up a water deficit. The overpumping of aquifers, now commonplace on every continent, has led to falling water tables as pumping exceeds aquifer recharge from precipitation. Irrigation problems are as old as irrigation itself, but this is a new threat, one that has evolved over the last half-century with the advent of diesel pumps and powerful electrically driven pumps.

Water tables are falling under large expanses of the three leading food-producing countries—China, India, and the United States. Under the North China Plain, which accounts for 25 percent of China's grain harvest, the water table is falling by roughly 1.5 meters (5 feet) per year. The same thing is happening under much of India, particularly the Punjab, the country's breadbasket. In the United States, water tables are falling under the grain-growing states of the southern Great Plains, shrinking the irrigated area.[14]

The diversion of water to provide supplies for irrigation and for cities is also excessive, leaving little or no water in some rivers. The Colorado, the major river in the southwestern United States, now

rarely makes it to the sea. China's Yellow River, the cradle of Chinese civilization, runs dry for part of each year, depriving farmers in its lower reaches of irrigation water. The Indus and the Ganges barely reach the sea during the dry season. Little water from the Nile reaches the Mediterranean at any time. Draining rivers dry disrupts the symbiotic relationship between the oceans and the continents. The oceans water the continents as moisture-laden air masses move inland, and the continents nourish the oceans as the returning water carries nutrients with it.[15]

Economic demands on forests are also excessive. Trees are being cut or burned faster than they can regenerate or be planted. Overharvesting is common in many regions, including Southeast Asia, West Africa, and the Brazilian Amazon. Worldwide, forests are shrinking by over 9 million hectares per year, an area equal to Portugal.[16]

In addition to being overharvested, some rainforests are now being destroyed by fire. Healthy rainforests do not burn, but logging and the settlements that occur along logging roads have fragmented and dried out tropical rainforests to the point where they often will burn easily, ignited by a lightning strike or set afire by opportunistic plantation owners, farmers, and ranchers desiring more land.

In the late summer of 1997, during an El Niño–induced drought, tropical rainforests in Borneo and Sumatra burned out of control. This conflagration made the news because the smoke drifting over hundreds of kilometers affected people not only in Indonesia but also in Malaysia, Singapore, Viet Nam, Thailand, and the Philippines. A reported 1,100 airline flights in the region were canceled due to the smoke. Motorists drove with their headlights on during the day, trying to make their way through the thick haze. Millions of people became physically sick.[17]

Deforestation can be costly. Record flooding in the Yangtze River basin during the summer of 1998 drove 120 million people from their homes. Although initially referred to as a "natural disaster," the removal of 85 percent of the original tree cover in the basin had left little vegetative cover to hold the heavy rainfall.[18]

Deforestation also diminishes the recycling of water inland, thus reducing rainfall in the interior of continents. When rain falls on a healthy stand of dense forest, roughly one fourth runs off, returning to the sea, while three fourths evaporates, either directly or

through transpiration. When land is cleared for farming or grazing or is clearcut by loggers, this ratio is reversed—three fourths of the water returns to the sea and one fourth evaporates to be carried further inland. As deforestation progresses, nature's mechanism for watering the interior of large continents such as Africa and Asia is weakening.[19]

Evidence of excessive human demands can also be seen in the oceans. As the human demand for animal protein has climbed over the last several decades, it has begun to exceed the sustainable yield of oceanic fisheries. As a result, two thirds of oceanic fisheries are now being fished at their sustainable yield or beyond. Many are collapsing. In 1992, the rich Newfoundland cod fishery that had been supplying fish for several centuries collapsed abruptly, costing 40,000 Canadians their jobs. Despite a subsequent ban on fishing, nearly a decade later the fishery has yet to recover.[20]

Farther to the south, the U.S. Chesapeake Bay has experienced a similar decline. A century ago, this extraordinarily productive estuary produced over 100 million pounds of oysters a year. In 1999, it produced barely 3 million pounds. The Gulf of Thailand fishery has suffered a similarly dramatic decline: depleted by overfishing, the catch has dropped by over 80 percent since 1963, prompting the Thai Fisheries Department to ban fishing in large areas.[21]

The world is also losing its biological diversity as plant and animal species are destroyed faster than new species evolve. This biological impoverishment of the earth is the result of habitat destruction, pollution, climate alteration, and hunting. With each update of its *Red List of Threatened Species*, the World Conservation Union–IUCN shows us moving further into a period of mass extinction. In the latest assessment, released in 2000, IUCN reports that one out of eight of the world's 9,946 bird species is in danger of extinction, as is one in four of the 4,763 mammal species and nearly one third of all 25,000 fish species.[22]

Some countries have already suffered extensive losses. Australia, for example, has lost 16 of 140 mammal species over the last two centuries. In the Colorado River system of the southwestern United States, 29 of 50 native species of fish have disappeared partly because their river habitats were drained dry. Species lost cannot be regained. As a popular bumper sticker aptly points out, "Extinction is forever."[23]

The economic benefits of the earth's diverse array of life are countless. They include not only the role of each species in maintaining the particular ecosystem of which it is a part, but economic roles as well, such as providing drugs and germplasm. As diversity diminishes, nature's pharmacy shrinks, depriving future generations of new discoveries.

Even as expanding economic activity has been creating biological deficits, it has been upsetting some of nature's basic balances in other areas. With the huge growth in burning of fossil fuels since 1950, carbon emissions have overwhelmed the capacity of the earth's ecosystem to fix carbon dioxide. The resulting rise in atmospheric CO_2 levels is widely believed by atmospheric scientists to be responsible for the earth's rising temperature. The 14 warmest years since recordkeeping began in 1866 have all occurred since 1980.[24]

One consequence of higher temperatures is more energy driving storm systems. Three powerful winter storms in France in December 1999 destroyed millions of trees, some of which had been standing for centuries. Thousands of buildings were demolished. These storms, the most violent on record in France, wreaked more than $10 billion worth of damage—$170 for each French citizen. Nature was levying a tax of its own on fossil fuel burning.[25]

In October 1998, Hurricane Mitch—one of the most powerful storms ever to come out of the Atlantic—moved through the Caribbean and stalled for several days on the coast of Central America. While there, it acted as a huge pump pulling water from the ocean and dropping it over the land. Parts of Honduras received 2 meters of rainfall within a few days. So powerful was this storm and so vast the amount of water it dropped on Central America that it altered the topography, converting mountains and hills into vast mud flows that simply inundated whole villages, claiming an estimated 10,000 lives. Four fifths of the crops were destroyed. The huge flow of rushing water removed all the topsoil in many areas, ensuring that this land will not be farmed again during our lifetimes.[26]

The overall economic effect of the storm was devastating. The wholesale destruction of roads, bridges, buildings, and other infrastructure set back the development of Honduras and Nicaragua by decades. The estimated $8.5 billion worth of damage in the region approached the gross domestic product of both countries combined.[27]

Natural disasters are on the increase. Munich Re, one of the world's largest re-insurance companies, reported that three times as many great natural catastrophes occurred during the 1990s as during the 1960s. Economic losses increased eightfold. Insured losses multiplied 15-fold. Although Munich Re's classification does not distinguish between natural and human-induced catastrophes, much of the increase appears to be due to catastrophes, including storms, droughts, and wild fires that are either exacerbated or caused by human activities.[28]

Insurers are keenly aware that even modest changes in climate can lead to quantum jumps in damage. For example, a 10-percent increase in a storm's wind speed can double the damage it inflicts. The cost of dealing with rising sea level from a modest temperature rise could easily overwhelm the economies of many countries.[29]

Andrew Dlugolecki, a senior officer at the CGMU Insurance Group—Britain's largest insurance group—reports that property damage worldwide is rising roughly 10 percent a year. He believes that we are only beginning to see the economic fallout from climate change. At this rate of growth, by 2065 the amount of damage would exceed the projected gross world product. Well before then, Dlugolecki notes, the world would face bankruptcy.[30]

Perhaps the most disturbing consequence of rising temperature is ice melting. Over the last 35 years, the ice covering the Arctic Sea has thinned by 42 percent. A study by two Norwegian scientists projects that within 50 years there will be no summer ice left in the Arctic Sea. The discovery of open water at the North Pole by an ice breaker cruise ship in mid-August 2000 stunned many in the scientific community.[31]

This particular thawing does not affect sea level because the ice that is melting is already in the ocean. But the Greenland ice sheet is also starting to melt. Greenland is three times the size of Texas and the ice sheet is up to 2 kilometers (1.2 miles) thick in some areas. An article in *Science* notes that if the entire ice sheet were to melt, it would raise sea level by some 7 meters (23 feet), inundating the world's coastal cities and Asia's rice-growing river floodplains. Even a 1-meter rise would cover half of Bangladesh's riceland, dropping food production below the survival level for millions of people.[32]

As the twenty-first century begins, humanity is being squeezed between deserts expanding outward and rising seas encroaching

inward. Civilization is being forced to retreat by forces it has created. Even as population continues to grow, the habitable portion of the planet is shrinking.

Aside from climate change, the economic effects of environmental destruction and disruption have been mostly local—collapsing fisheries, abandoned cropland, and shrinking forests. But if local damage keeps accumulating, it will eventually affect global economic trends. In an increasingly integrated global economy, local ecosystem collapse can have global economic consequences.

Lessons from the Past

In *The Collapse of Complex Civilizations*, Joseph Tainter describes the decline of early civilizations and speculates about the causes. Was it because of the degradation of their environment, climate change, civil conflict, foreign invaders? Or, he asks, "is there some mysterious internal dynamic to the rise and fall of civilizations?"[33]

As he ponders the contrast between civilizations that once flourished and the desolation of the sites they occupied, he quotes archeologist Robert McC. Adams, who described the site of the ancient Sumerian civilization located on the central floodplain of the Euphrates River, an empty, desolate area now outside the frontiers of cultivation. Adams described how the "tangled dunes, long disused canal levees, and the rubble-strewn mounds of former settlement contribute only low, featureless relief. Vegetation is sparse, and in many areas it is almost wholly absent.…Yet at one time, here lay the core, the heartland, the oldest urban, literate civilization in the world."[34]

The early Sumerian civilization of the fourth millennium BC was remarkable, advancing far beyond any that had existed before. Its irrigation system, based on sophisticated engineering concepts, created a highly productive agriculture, one that enabled farmers to produce a surplus of food that supported the formation of the first cities. Managing the irrigation system required a complex social organization, one that may have been more sophisticated than any that had gone before. The Sumerians had the first cities and the first written language, the cuneiform script. They were probably as excited about it as we are today about the Internet.[35]

It was an extraordinary civilization, but there was an environmental flaw in the design of the irrigation system, one that would eventually undermine its agricultural economy. Water from behind

dams was diverted onto the land, raising crop yields. Some of the water was used by the crops, some evaporated into the atmosphere, and some percolated downward. Over time, this percolation slowly raised the water table until eventually it approached the surface of the land. When it reached a few feet from the surface it began to restrict the growth of deep-rooted crops. Somewhat later, as the water climbed to within inches of the surface, it began to evaporate into the atmosphere. As this happened, the salt in the water was left behind. Over time, the accumulation of salt reduced the productivity of the land. The environmental flaw was that there was no provision for draining the water that percolated downward.[36]

The initial response of the Sumerians to declining wheat yields was to shift to barley, a more salt-tolerant plant. But eventually the yields of barley also declined. The resultant shrinkage of the food supply undermined the economic foundation of this great civilization.[37]

The New World counterpart to Sumer is the Mayan civilization that developed in the lowlands of what is now Guatemala. It flourished from AD 250 until its collapse around AD 900. Like the Sumerians, the Mayans had developed a sophisticated, highly productive agriculture, one that relied on raised plots of earth surrounded by canals that supplied water.[38]

As with Sumer, the Mayan demise was apparently linked to a failing food supply. For this New World civilization, it was deforestation and soil erosion that undermined agriculture. Food scarcity may then have triggered civil conflict among the various Mayan cities as they competed for food.[39]

During the later centuries of the Mayan civilization, a new society was evolving on Easter Island, some 166 square kilometers of land in the South Pacific roughly 3,200 kilometers west of South America and 2,200 kilometers from Pitcairn Island, the nearest habitation. Settled around AD 400, this civilization flourished on a volcanic island with rich soils and lush vegetation, including trees that grew 25 meters tall with trunks 2 meters in diameter. Archeological records indicate that the islanders ate mainly seafood, principally dolphins—a mammal that could only be caught by harpoon from large sea-going canoes since it was not locally available in large numbers.[40]

The Easter Island society flourished for several centuries, reach-

ing an estimated population of 20,000. As its human numbers gradually increased, tree cutting exceeded the sustainable yield of forests. Eventually the large trees needed to build the sturdy, ocean-going canoes disappeared, depriving islanders of access to the dolphins, thus dramatically shrinking the island's seafood supply. The archeological record shows that at some point human bones became intermingled with the dolphin bones, suggesting a desperate society that had resorted to cannibalism. Today the island is occupied by some 2,000 people.[41]

These are just three of the early civilizations that declined apparently because at some point they moved onto an economic path that was environmentally unsustainable. We, too, are on such a path. Any one of several trends of environmental degradation could undermine civilization as we know it. Just as the irrigation system that defined the early Sumerian economy had a flaw, so too does the fossil fuel energy system that defines our modern economy. It is raising CO_2 levels in the atmosphere and thus altering the earth's climate.

Whether it was from the salting of the land in Sumer, the soil erosion of the Mayans, or the loss of the distant-water fishing capacity of the Easter Islanders, collapse of the early civilizations appears to have been associated with a decline in food supply. Today the addition of 80 million people a year to world population at a time when water tables are falling suggests that food supplies again may be the vulnerable link between the environment and the economy.[42]

The Sumerians did not know that the New World even existed, much less that it would one day support flourishing civilizations, such as the Mayans. The Mayans had no idea that Easter Island existed. Each of these civilizations collapsed in isolation, with no effect on the others. But today, in an integrated global economy, a collapse in one country or region will affect all of us. Even a currency devaluation in a developing country, such as Indonesia, can send shock waves through Wall Street half a world away.

One unanswerable question about these earlier civilizations was whether they knew what was causing their decline. Did the Sumerians understand that rising salt content in the soil was reducing their wheat yields? If they knew, were they simply unable to muster the political support needed to lower water tables, just as we today are struggling unsuccessfully to lower carbon emissions?

Learning from China

The flow of startling information from China helps us understand why our economy cannot take us where we want to go. Not only is China the world's most populous country, with nearly 1.3 billion people, but since 1980 it has been the world's fastest-growing economy—expanding more than fourfold. In effect, China is telescoping history, demonstrating what happens when large numbers of poor people rapidly become more affluent.[43]

As incomes have climbed in China, so has consumption. The Chinese have already caught up with Americans in pork consumption per person and they are now concentrating their energies on increasing beef production. Raising per capita beef consumption in China to that of the average American would take 49 million additional tons of beef. If all this were to come from putting cattle in feedlots, American-style, it would require 343 million tons of grain a year, an amount equal to the entire U.S. grain harvest.[44]

In Japan, as population pressures on the land mounted during a comparable stage of its economic development, the Japanese turned to the sea for their animal protein. Last year, Japan consumed nearly 10 million tons of seafood. If China, with 10 times as many people as Japan, were to try to move down this same path, it would need 100 million tons of seafood—the entire world fish catch.[45]

In 1994, the Chinese government decided that the country would develop an automobile-centered transportation system and that the automobile industry would be one of the engines of future economic growth. Beijing invited major automobile manufacturers, such as Volkswagen, General Motors, and Toyota, to invest in China. But if Beijing's goal of an auto-centered transportation system were to materialize and the Chinese were to have one or two cars in every garage and were to consume oil at the U.S. rate, China would need over 80 million barrels of oil a day—slightly more than the 74 million barrels per day the world now produces. To provide the required roads and parking lots, it would also need to pave some 16 million hectares of land, an area equal to half the size of the 31 million hectares of land currently used to produce the country's 132-million-ton annual harvest of rice, its leading food staple.[46]

Similarly, consider paper. As China modernizes, its paper consumption is rising. If annual paper use in China of 35 kilograms per person were to climb to the U.S. level of 342 kilograms, China

would need more paper than the world currently produces. There go the world's forests.[47]

We are learning that the western industrial development model is not viable for China, simply because there are not enough resources for it to work. Global land and water resources are not sufficient to satisfy the growing grain needs in China if it continues along the current economic development path. Nor will the existing fossil-fuel-based energy economy supply the needed energy, simply because world oil production is not projected to rise much above current levels in the years ahead. Apart from the availability of oil, if carbon emissions per person in China ever reach the U.S. level, this alone would roughly double global emissions, accelerating the rise in the atmospheric CO_2 level.[48]

China faces a formidable challenge in fashioning a development strategy simply because of the density of its population. Although it has almost exactly the same amount of land as the United States, most of China's 1.3 billion people live in a 1,500-kilometer strip on the eastern and southern coasts. Reaching the equivalent population density in the United States would require squeezing the entire U.S. population into the area east of the Mississippi and then multiplying it by four.[49]

Interestingly, the adoption of the western economic model for China is being challenged from within. A group of prominent scientists, including many in the Chinese Academy of Sciences, wrote a white paper questioning the government's decision to develop an automobile-centered transportation system. They pointed out that China does not have enough land both to feed its people and to provide the roads, highways, and parking lots needed to accommodate the automobile. They also noted the heavy dependence on imported oil that would be required and the potential air pollution and traffic congestion that would result if they followed the U.S. path.[50]

If the fossil-fuel-based, automobile-centered, throwaway economy will not work for China, then it will not work for India with its 1 billion people, or for the other 2 billion people in the developing world. In a world with a shared ecosystem and an increasingly integrated global economy, it will ultimately not work for the industrial economies either.

China is showing that the world cannot remain for long on the current economic path. It is underlining the urgency of restructur-

ing the global economy, of building a new economy—an economy designed for the earth.

The Acceleration of History

The pace of change is reaching an extraordinary rate, driven in part by technological innovation. Bill Joy, cofounder and chief scientist of Sun Microsystems, warned in an early 2000 article in *Wired* magazine that rapid advances in robotics, genomics, and nanotechnology could yield potentially unmanageable problems. He is particularly concerned that our growing dependence on ever more intelligent computers could one day enable them to dominate us.[51]

Rapidly advancing technology is accelerating history, making it difficult for social institutions to manage it effectively. This is also true for unprecedented world population growth, even faster economic growth, and the increasingly frequent collisions between the expanding economy and the limits of the earth's natural systems. The current rate of change has no precedent.

Until recently, population growth was so slow that it aroused little concern. But since 1950 we have added more people to world population than during the preceding 4 million years since our early ancestors first stood upright. Economic expansion in earlier times was similarly slow. To illustrate, growth in the world economy during the year 2000 exceeded that during the entire nineteenth century.[52]

Throughout most of human history, the growth of population, the rise in income, and the development of new technologies were so slow as to be imperceptible during an individual life span. For example, the climb in grainland productivity from 1.1 tons per hectare in 1950 to 2.8 tons per hectare in 2000 exceeds that during the 11,000 years from the beginning of agriculture until 1950.[53]

The population growth of today has no precedent. Throughout most of our existence as a species, our numbers were measured in the thousands. Today, they measure in the billions. Our evolution has prepared us to deal with many threats, but perhaps not with the threat we pose to ourselves with the uncontrolled growth in our own numbers.

The world economy is growing even faster. The sevenfold growth in global output of goods and services since 1950 dwarfs anything in history. In the earlier stages of the Industrial Revolution, eco-

nomic expansion rarely exceeded 1 or 2 percent a year. Developing countries that are industrializing now are doing so much faster than their predecessors simply because they do not have to invent the technologies needed by a modern industrial society, such as power plants, automobiles, and refrigerators. They can simply draw on the experiences and technology of those that preceded them.[54]

More sophisticated financial institutions enable societies to mobilize the capital needed for investment today more easily than in the past. As a result, the countries that were successfully industrializing in the late twentieth century did so at a record rate. Economic growth in the developing countries of East Asia, for instance, has averaged almost 7 percent annually since 1990—far higher than growth rates in industrial countries at any time in their history.[55]

In another example of rapid change, since 1974 some 28 new infectious diseases have been identified—ranging from HIV, which has claimed 22 million lives, to new variant Creutzfeldt-Jakob disease, the human form of bovine spongiform encephalopathy ("mad cow disease"), with nearly 100 known cases. Some disease agents are new; others that were located in remote regions are simply being linked to the rest of the world by modern transport systems.[56]

The pace of history is also accelerating as soaring human demands collide with the earth's natural limits. National political leaders are spending more time dealing with the consequences of the collisions described earlier—collapsing fisheries, falling water tables, food shortages, and increasingly destructive storms—along with a steadily swelling international flow of environmental refugees and the many other effects of overshooting natural limits. As change has accelerated, the situation has evolved from one where individuals and societies change only rarely to one where they change continuously. They are changing not only in response to growth itself, but also to the consequences of growth.

The central question is whether the accelerating change that is an integral part of the modern landscape is beginning to exceed the capacity of our social institutions to cope with change. Change is particularly difficult for institutions dealing with international or global issues that require a concerted, cooperative effort by many countries with contrasting cultures if they are to succeed. For example, sustaining the existing oceanic fish catch may be possible only if numerous agreements are reached among countries on the limits to fishing in individual oceanic fisheries. And can govern-

ments, working together at the global level, move fast enough to stabilize climate before it disrupts economic progress?

The issue is not whether we know what needs to be done or whether we have the technologies to do it. The issue is whether our social institutions are capable of bringing about the change in the time available. As H.G. Wells wrote in *The Outline of History*, "Human history becomes more and more a race between education and catastrophe."[57]

The Option: Restructure or Decline

Whether we study the environmental undermining of earlier civilizations or look at how adoption of the western industrial model by China would affect the earth's ecosystem, it is evident that the existing industrial economic model cannot sustain economic progress. In our shortsighted efforts to sustain the global economy, as currently structured, we are depleting the earth's natural capital. We spend a lot of time worrying about our economic deficits, but it is the ecological deficits that threaten our long-term economic future. Economic deficits are what we borrow from each other; ecological deficits are what we take from future generations.[58]

Herman Daly, the intellectual pioneer of the fast-growing field of ecological economics, notes that the world "has passed from an era in which manmade capital represented the limiting factor in economic development (an 'empty' world) to an era in which increasingly scarce natural capital has taken its place (a 'full' world)." When our numbers were small relative to the size of the planet, it was humanmade capital that was scarce. Natural capital was abundant. Now that has changed. As the human enterprise continues to expand, the products and services provided by the earth's ecosystem are increasingly scarce, and natural capital is fast becoming the limiting factor while humanmade capital is increasingly abundant.[59]

Transforming our environmentally destructive economy into one that can sustain progress depends on a Copernican shift in our economic mindset, a recognition that the economy is part of the earth's ecosystem and can sustain progress only if it is restructured so that it is compatible with it. The preeminent challenge for our generation is to design an eco-economy, one that respects the principles of ecology. A redesigned economy can be integrated into the ecosystem in a way that will stabilize the relationship between the two, enabling economic progress to continue.

Unfortunately, present-day economics does not provide the conceptual framework needed to build such an economy. It will have to be designed with an understanding of basic ecological concepts such as sustainable yield, carrying capacity, nutrient cycles, the hydrological cycle, and the climate system. Designers must also know that natural systems provide not only goods, but also services—services that are often more valuable than the goods.

We know the kind of restructuring that is needed. In simplest terms, our fossil-fuel-based, automobile-centered, throwaway economy is not a viable model for the world. The alternative is a solar/hydrogen energy economy, an urban transport system that is centered on advanced-design public rail systems and that relies more on the bicycle and less on the automobile, and a comprehensive reuse/recycle economy. And we need to stabilize population as soon as possible.

How do we achieve this economic transformation when all economic decisionmakers—whether political leaders, corporate planners, investment bankers, or individual consumers—are guided by market signals, not the principles of ecological sustainability? How do we integrate ecological awareness into economic decisionmaking? Is it possible for all of us who are making economic decisions to "think like ecologists," to understand the ecological consequences of our decisions? The answer is probably not. It simply may not be possible.

But there may be another approach, a simpler way of achieving our goal. Everyone making economic decisions relies on market signals for guidance. The problem is that the market often fails to tell the ecological truth. It regularly underprices products and services by failing to incorporate the environmental costs of providing them.

Compare, for example, the cost of wind-generated electricity with that from a coal-fired power plant. The cost of the wind-generated electricity reflects the costs of manufacturing the turbine, installing it, maintaining it, and delivering the electricity to consumers. The cost of the coal-fired electricity includes building the power plant, mining the coal, transporting it to the power plant, and distributing the electricity to consumers. What it does not include is the cost of climate disruption caused by carbon emissions from coal burning—whether it be more destructive storms, melting ice caps, rising sea level, or record heat waves. Nor does it

include the damage to freshwater lakes and forests from acid rain, or the health care costs of treating respiratory illnesses caused by air pollution. Thus the market price of coal-fired electricity greatly understates its cost to society.

One way to remedy this situation would be to have environmental scientists and economists work together to calculate the cost of climate disruption, acid rain, and air pollution. This figure could then be incorporated as a tax on coal-fired electricity that, when added to the current price, would give the full cost of coal use. This procedure, followed across the board, would mean that all economic decisionmakers—governments and individual consumers—would have the information needed to make more intelligent, ecologically responsible decisions.

We can now see how to restructure the global economy so as to restore stability between the economy and the ecosystem on which it rests. When I helped to pioneer the concept of environmentally sustainable economic development some 27 years ago, at the newly formed Worldwatch Institute, I had a broad sense of what the new economy would look like. Now we can see much more of the detail. We can build an eco-economy with existing technologies. It is economically feasible if we can get the market to tell us the full cost of the products and services that we buy.

The question is not how much will it cost to make this transformation but how much it will cost if we fail to do it. Øystein Dahle, retired Vice President of Esso for Norway and the North Sea, observes, "Socialism collapsed because it did not allow prices to tell the economic truth. Capitalism may collapse because it does not allow prices to tell the ecological truth."[60]

This book has three purposes. The first is to make the case that we have no alternative to restructuring the economy if we want economic progress to continue in the decades ahead. The second is to describe not only the broad structure of the eco-economy, but some of its details. And the third is to outline a strategy for getting from here to there in the time available.

Building an eco-economy is exciting and satisfying. It means we can live in a world where energy comes from wind turbines instead of coal mines, where recycling industries replace mining industries, and where cities are designed for people, not for cars. And perhaps most important of all, we will have the satisfaction of building an economy that will support, not undermine, future generations.

I

A Stressed Relationship