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ARE WE ON EASTER ISLAND?

Energy is a natural resource and, for the most part, finite. Exhaustion of fossil fuels (coal, oil, and natural gas) is not imminent, although we may be at the onset of negotiating a slippery slope with regard to oil production. Interestingly, we have a history of responding to finite natural resources in danger of exhaustion. We exhausted forests in Europe at the start of the Industrial Age in our quest for making glass and metals, and we nearly drove whales to the point of extinction during the nineteenth century in our quest for whale oil. Fortunately, we found ways to avert what could have been a terminal crisis. The forests in Europe were saved from the axe by the discovery of coal as an alternative to wood in glass- and metal-making. Whales were saved from extinction by finding an alternative source for their oil for lighting in the form of kerosene. In the twentieth century we took effective action to rejuvenate a threatened species of marine animal life, but at the same time we discovered the technology to strip-mine the open oceans of fish life. As we exhaust open-ocean fishing, an alternative has been found in aquaculture or fish farming. Aquaculture is similar to relying on sustainable biofuels whereas open-ocean fishing, when fish are caught faster than they can reproduce, is similar to exhausting fossil fuels.

In the case of energy, it is true that immense energy reserves have been found that have kept up with our horrific appetite for energy, making mincemeat of Theodore Roosevelt's prediction, from the vantage point of the early twentieth century, that we will soon exhaust our natural resources. A key question facing us is whether the future pace of discovery can keep ahead of our growing appetite for energy; that is, will Roosevelt ultimately be proven right? Just because we run short of a natural resource does not necessarily mean that we can find an alternative. That is the tragedy of Easter Island.

EASTER ISLAND

Easter Island is over 2,000 miles from Tahiti and Chile. To the original inhabitants, Easter Island was an isolated island of finite resources surrounded by a seemingly infinite ocean. What happened on Easter Island when it ultimately exhausted its finite resources is pertinent because Earth is an isolated planet of finite resources surrounded by seemingly infinite space. Whether we admit it or not, we are in danger of exhausting our natural resources. Rough, and some deem optimistic, estimates are forty years for oil, sixty years for natural gas, and a one hundred twenty years for coal. These are not particularly comforting when viewed from the perspective of a six thousand year history of civilization. Like the Easter Islanders who had nowhere to go, this is our home planet now and for the foreseeable future. Space travel is a long way off, and flying off to Mars to escape a manmade calamity on Earth is not a particularly inviting prospect.

Examination of the soil layers on Easter Island, or Rapa Nui to the present inhabitants, reveals an island with abundant plant and animal life that existed for tens of thousands of years. Around

400 CE, the island was discovered and settled by Polynesians, who originally named the island Te Pito O Te Henua (Navel of the World). The natives survived on the bounty of natural animal and plant life on the island and fish in the surrounding waters. Critical for survival was the eighty-foot tall Easter Island palm that provided sap and nuts for human consumption and canoes for fishing. The palms also provided the means to move the massive stone Moai, stone figures for which the island is famous, which now stand in mute testimony to an ecological catastrophe that unfolded around 1500. By then, the estimated population had grown to somewhere between 10,000 and 15,000 inhabitants.

This sounds like an awful lot of people descended from a few settlers, but this is the nature of exponential growth. If a party of ten people originally settled on Easter Island and grew at a relatively modest 1 percent per year (about the current growth rate in world population), the number of Easter Islanders would double about every seventy years. There were nearly sixteen doublings of the population in the 1,100 years from 400 to 1500 CE. Double ten sixteen times and see what you get. In theory the population would have grown to 567,000, a mathematical consequence of compound exponential growth at 1 percent per year over 1,100 years. It would never have reached this level because, as proven in 1500, a population in excess of 10,000 was sufficient to exhaust the island's natural resources.

A growing population increased the demand for meat, which eventually led to the natives feasting on the last animal. More people and no animals promoted more intensive tilling of the land, which first had to be cleared of the palms. With fewer palms, erosion increased and, coupled with the pressure to grow more crops, soil fertility declined. Of course the palms did not go to waste as they were needed to support the leading industry on Easter Island: the construction and moving of the Moai, plus of course, canoes. Fish became more important in the diet as the population grew, the animals disappeared, and crop yields fell. Around 1500, the last palm tree was cut down. Bloody intertribal warfare, cannibalism, and starvation marked the demise of a civilization.

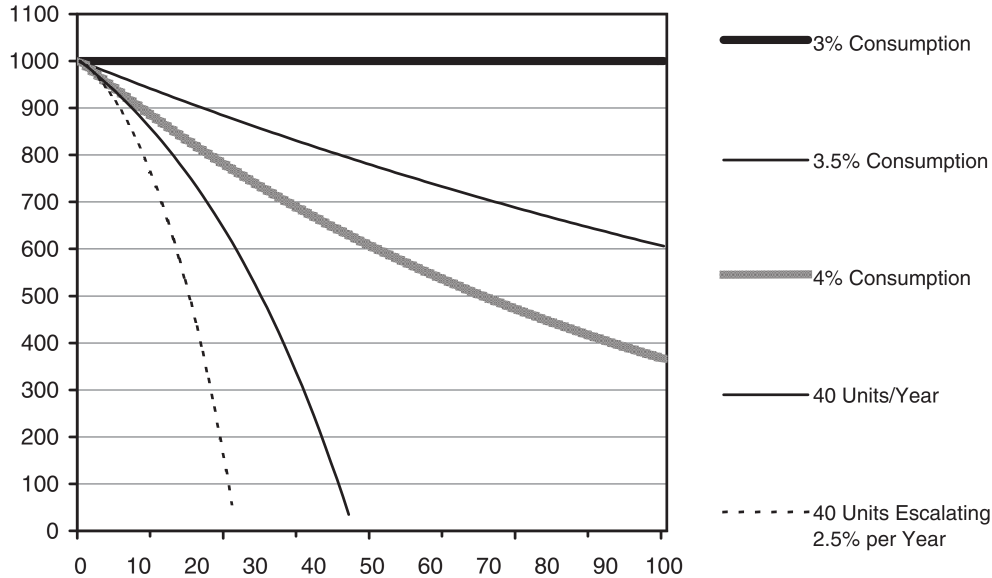
On Easter of 1722, the Dutch explorer Jacob Roggeveen rediscovered the island. It presented a great mystery, as the few surviving and utterly impoverished natives had no memory of the tragedy nor did they understand the meaning of the Moai. The gift of Western civilization—infectious disease—ultimately reduced the native population to a remnant of 111 by 1800. In 1888, when the island was annexed by Chile and renamed Rapa Nui, the population had risen to 2,000 (a growth rate considerably in excess of 1 percent!).

THE MATHEMATICS OF EXTINCTION

Suppose that we depend on a forest for supplying wood for fuel and building material. If the forest grows at 3 percent per year and we remove 2 percent of the forest per year, the resource will last forever (a sustainable resource). The forest also lasts forever if 3 percent is removed per year, but care has to be exercised to ensure that removal does not exceed 3 percent. If consumption exceeds 3 percent as a consequence of a growing population that needs more wood for fuel and shelter, or if a new technology is introduced that consumes a great deal of wood, such as glass- and metal-making, then the forest will eventually be consumed (a nonsustainable resource).

Suppose that a forest consists of 1,000 units of usable wood that increases naturally by 3 percent per year. Figure 1.1 shows what happens to the forest as a resource in terms of units of usable wood when consumption is 3, 3.5, and 4 percent per year. While the forest is a sustainable resource if consumption is limited to 3 percent, in a century the forest will be reduced to 600 and 380 units for consumption rates of 3.5 and 4 percent respectively. One hundred years in the recorded 6,000-year history of humanity is not very long; for a growing minority, it is a single lifetime. But this does

Figure 1.1 **Exhausting a Natural Resource**



not accurately describe the situation. What is wrong with this projection is that demand declines in absolute terms over time. For example, in the first year the forest gains 30 units and consumption at 4 percent is 40 units, leaving 990 units for the next year. When the forest is down to 800 units, consumption at 4 percent has been reduced from 40 to 32 units.

This is not realistic; there is no reason for demand to decline simply because supply is dwindling. Suppose that consumption remains constant at 40 units with 3 percent growth in forest reserves. Then, as Figure 1.1 shows, the forest is transformed to barren land in 47 years. The final curve is the most realistic. It shows what would happen if consumption climbs at 1 unit per year; 40 units in the first year, 41 units the second, and so on, which is reflective of a growing population. Now the forest is gone in 30 years, a single generation.

Yet, even this projection is not realistic. Consumption, initially growing by 1 unit a year, declines in relative terms over time. For instance, when consumption increases from 40 to 41 units, growth is 2.5 percent; from 50 to 51 units, growth has declined to 2 percent. Another curve could be constructed holding consumption growth at 2.5 percent, based on a starting point of 40 units per year. But the point has already been made: The resource is exhausted within a single generation.

Before the resource is exhausted, other mitigating factors come into play. One is price, a factor not at play on Easter Island. As the forest diminishes in size and consumers and suppliers realize that wood supplies are becoming increasingly scarce, price would increase. The more serious the situation becomes, the higher the price. Higher prices dampen demand and act as an incentive to search for other forests or alternative sources for wood such as coal for energy and plastic for wood products (neither option available to the Easter Islanders).

Price would certainly have caused a change of some sort to deal with the oncoming crisis, but would not have affected the eventual outcome. A very high price for the last Easter Island palm would not have saved a civilization from extinction. The individual who became rich selling the last palm would have to spend his last dime buying the last fish. Easter Island is not the only civilization that collapsed from a shortage of natural resources. It is believed that the fall in agricultural output from a prolonged drought caused the demise of the Mayan civilization in Central America. Ruins of dead civilizations litter the earth, a humbling reminder of their impermanence.

PROGRESS IS OUR MOST IMPORTANT PRODUCT

About one-third of the earth's population still depends on wood as a primary energy source. Unfortunately, removing forests to clear land for agriculture is often considered a mark of progress. Where cleared land stopped and forests began marked the boundaries of the Roman Empire. Agriculture transformed war-loving hunter-gatherers into law-abiding agrarians. The resuscitation of civilization during the Middle Ages was evidenced by forests and abandoned lands transformed to vineyards and other forms of agricultural enterprise by monks. Removal of forests to support a growing population became too much of a good thing. The first energy crisis occurred early in the Industrial Revolution when wood demand for housing, heating, and the new industries of glass- and metal-making exhausted a natural resource. A crisis turning into a calamity was averted by the discovery of coal in England and forests in North America.

The growth of the United States as a nation can be traced by the clearing of a large portion of the forest covering the eastern half of the nation for farmland. This was a visual sign of progress for pioneers seeking a new life in the Americas. Despite environment protestations to the contrary, clearing forests is still considered a sign of progress. We are intentionally burning down and clearing huge portions of the rain forests in the Amazon and in Southeast Asia for cattle grazing and other forms of agriculture.

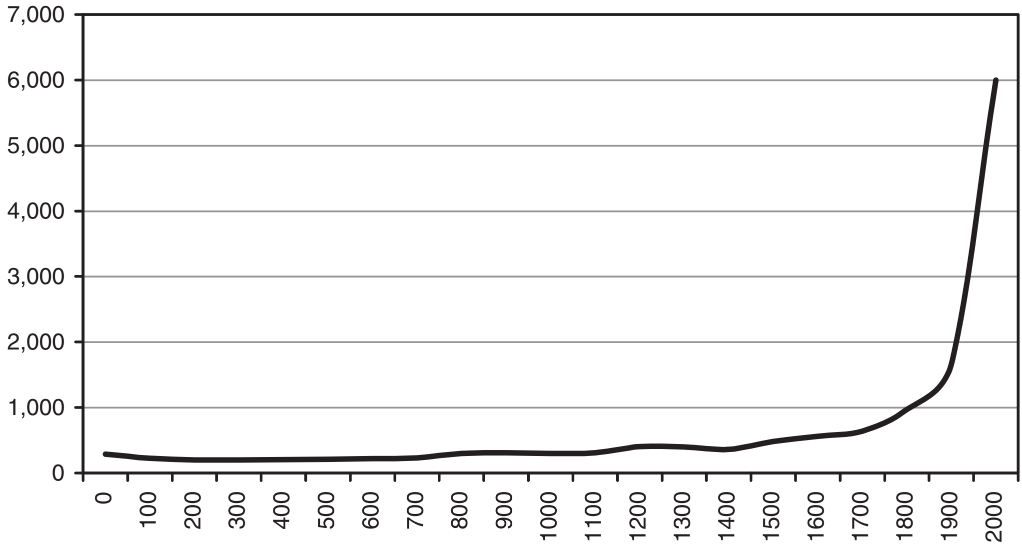
Burning wood or biomass faster than it can be replaced by natural growth adds carbon dioxide to the atmosphere. Burning fossil fuels (coal, oil, and natural gas) releases carbon dioxide previously removed from the atmosphere by plant, animal, and marine life millions of years ago. The increasing concentration of carbon dioxide in the atmosphere is blamed on both the continuing clearing of forests and our growing reliance on fossil fuels. At the same time, clearing forests and consuming energy are signs of economic progress to raise living standards. Although there is intense public pressure to reduce carbon dioxide emissions in Europe, Japan, Australia, and New Zealand, over half of the planet's population live in nations in South America and Asia where governments have been active in increasing carbon dioxide emissions in pursuit of economic development. However, in recent years, concerns have been raised on the effect of water and air pollution on the health of the people and efforts are being initiated to curb pollution.

Unlike the unhappy experience of the Easter Islanders, there are countervailing measures being taken to compensate for burning down vast tracts of the world's tropical forests. Tree farms and replanting previously harvested forests ensure a supply of raw materials for lumber and papermaking industries for their long-term sustainability. A number of public service organizations are dedicated to planting trees to combat the rising concentration of carbon dioxide in the atmosphere. An increasing carbon dioxide concentration in the atmosphere itself promotes plant growth that would be a natural countermeasure (an example of a negative feedback system). Yet despite human efforts to the contrary, the world's resource of forests continues to dwindle and the carbon dioxide concentration in the atmosphere continues to climb.

THE UNREMITTING RISE IN POPULATION

Both energy usage and pollution can be linked directly to population. Indeed, there are groups who advocate population reduction as the primary countermeasure to cut pollution of the land, air, and water. These groups have identified the true culprit of energy exhaustion and environmental pollution, but their suggested means of correcting the problem does not make for comfortable

Figure 1.2 **World Population**



reading. Figure 1.2 shows the world population since the beginning of the Christian era and its phenomenal growth since the Industrial Revolution. [1]

The world's population was remarkably stable up to 1000 CE. The Dark Age of political disorder and economic collapse following the fall of the Roman Empire around 400 CE was instrumental in suppressing population growth. The high death rate for infants and children and the short, dirty, brutish lives of those who survived childhood, coupled with the disintegration of society, prevented runaway population growth. After the Dark Age was over, the population began to grow accompanied by a period of global warming. This continued until the Black Death starting around 1350, which occurred during a period of global cooling. With several recursions over the next hundred years, the Black Death wiped out massive numbers of people in Asia and Europe. More than one-third of Europe's population were victims, with as much as two-thirds in certain areas. It took over a century for the population of Europe to recover to pre-plague levels.

The first billion in the world's population was reached around 1840. The second billion was reached around 1930, only ninety years later, despite the horrendous human losses during the First World War, the Russian Revolution and Civil War, and the Spanish Flu, a pandemic that wiped out 30–40 million lives. This pandemic cost more in human life than the combined efforts of those involved with perpetrating war and revolution and numerically, but not percentagewise, exceeded lives lost to the Black Death. It only took 30 years for the world population to reach its third billion in 1960, despite Stalin's execution of tens of millions of his own people by starvation and firing squad, Hitler's extermination of 12 million Jews and Slavs, plus the deaths of untold millions of military personnel and civilians during the Second World War. The fourth billion was reached fourteen years later in 1974 despite Mao Zedong's failed Great Leap Forward that caused the death of tens of millions from starvation and the genocide perpetuated by the Khmer Rouge in Cambodia, the fifth billion thirteen years later in 1987, and the sixth billion twelve years later in 1999. The seventh billion is projected to occur in 2011.

We should be justifiably proud of the medical advances that have drastically reduced the mortality rate of infant and childhood diseases. No one espouses going back to the days of Queen Anne

(1665–1714), ruler of England from 1702 until her death. Anne had the best medical care that royalty could buy. Yet she had the misfortune of having around six stillbirths plus another twelve who survived birth, but not her. She died at forty-nine without an heir to the throne. As much as we are grateful for advances in treating disease, there are mathematical consequences.

The quickening pace of adding increments of a billion to the population is not an increase in the growth rate but a property of the mathematics of growth. Going from 1 to 2 billion is a 100 percent gain in population, from 2 to 3 billion is a 50 percent gain, from 3 to 4 billion 33 percent, 4 to 5 billion 25 percent, 5 to 6 billion 20 percent, and 6 to 7 billion is 17 percent growth. Eventually only a 10 percent growth in population would be necessary to go from 10 to 11 billion. Thus, each billion increment of the world's population occurs more quickly for a constant population growth rate.

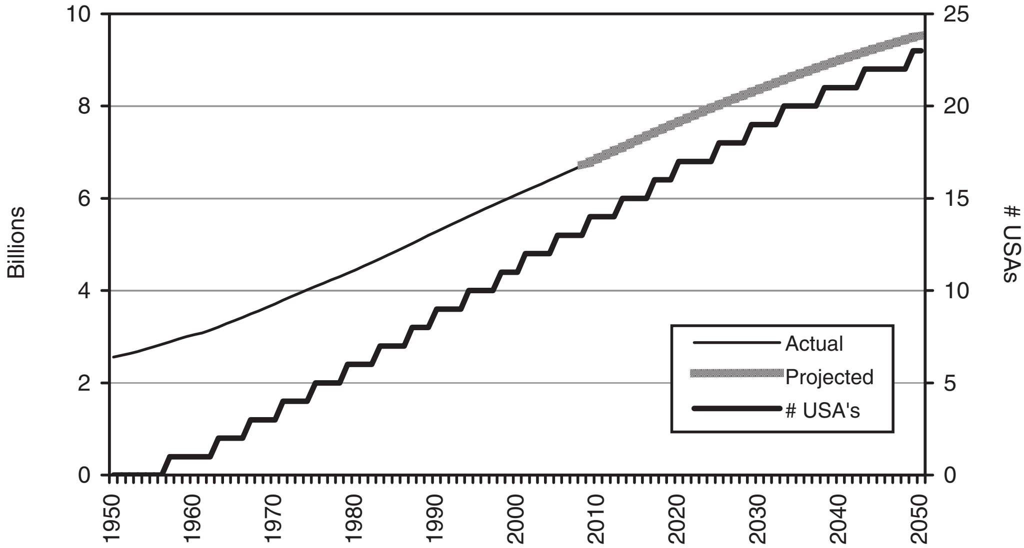
The earth is rapidly getting more crowded, yet there are some who say that we can sustain a much larger population. If every human being were to stand next to one another, how much of the earth would be covered with people? If we place every individual in a 3′×3′ square, enough space sufficient for everyone to stand but not lie down, we can get slightly over 3 million people into a square mile. The area to accommodate 6.8 billion people in 2009 is 2,200 square miles, or a square about 47 miles on a side. Thus, the world's population could fit, standing room only, in Delaware, the nation's second smallest state at just under 2,500 square miles, with a little room to spare.

Demographics affect energy consumption: The larger the number of people, the greater the energy consumption. One way to judge the future population is to calculate the portion of a nation below 15 years of age. A disproportionately high youthful population portends higher than average population growth as this segment reaches the childbearing years. On this basis, future population growth will be centered in the Middle East, Asia (excluding Japan), and South America. On the other hand, Europe, United States, Russia, and Japan have to deal with a growing geriatric generation that has ramifications on future population size and energy consumption.

As Europe and Japan exhibit essentially stagnant population growth, other nations would like to curb their growth. Some years ago, China took draconian efforts to contain its population growth at 1 billion people by restricting families to one child through forced abortions, and financial and even physical forms of punishment, for having more than the authorized number of children. Families restricted to one child preferred boys, which resulted in abortions or abandonment of baby girls. Having a society where males outnumber females may create a serious social problem as large numbers of males find themselves unable to find mates. Despite Herculean efforts to the contrary, the social experiment to contain the nation's population at 1 billion has obviously failed; China's current population is 1.3 billion and climbing.

The rate of world population growth expanded between 1951 and 1964, peaked, and then started a long-term decline, which is projected to be 0.5 percent per year. On a global scale, the average number of children per family has to decline to reduce the population growth rate. But other forces are at work that may effectively cut the increase in population growth, if not the population itself. The fall of communism in 1991, and the subsequent economic turmoil, brought about a decade of a declining birthrate and a shortening of the average life span, resulting in a negative population growth rate in Russia. Diseases such as HIV/AIDS are ravaging the population in sub-Saharan Africa along with social disintegration, civil upheaval, tribal warfare, and, on occasion, holocausts. Some rapidly growing nations such as Bangladesh must be close to, or have already exceeded, their capacity to adequately feed, clothe, and shelter their populations. Similar to Easter Island, Haiti has removed so many trees that the barren land is visible from space as is its boundary with the verdant Dominican Republic. Haitians cannot find sufficient wood to build shelters and burn as

Figure 1.3 **Actual and Projected World Population**



fuel. The removal of the forests has exposed hilltop soil to erosion, which, during the rainy season, has washed down and covered the fertile soil in the valleys, reducing food production. Haiti is on an irreversible course to environmental oblivion, but unlike the Easter Islanders, Haitians are not forced to remain in Haiti and starve: They can flee. Various forms of flu seem to be on the verge of jumping from animals to humans, which could bring on a new Spanish Flu-type pandemic. Modern means of travel make it nearly impossible to isolate or quarantine an outbreak of contagious diseases. Weapons of mass destruction and terrorism are other threats to human survival. Considering all these factors, the projected population of over 9 billion people by 2050, as shown in Figure 1.3, a 30 percent increase from current levels, is not a foregone conclusion.

In one century, we'll be adding the equivalent population of twenty-three United States of Americas (population increments of 300 million). This is a single, though long, lifetime. What will it be like in the succeeding hundred years? Exponential growth, like bacteria overflowing the confines of a Petri dish, is ultimately unsustainable.

THE CASE OF DOUBLE EXPONENTIAL GROWTH

An oil company executive once observed that the oil industry benefits from two exponential curves: population and per capita energy consumption. Both work together to promote a greater volume of consumption of oil products and, presumably, greater corporate revenues and profits.

To illustrate double exponential growth, suppose that the population is growing at 1 percent per year and per capita energy consumption is growing at 2 percent per year. Further, suppose that the initial total annual consumption of energy for 100 people is 500 barrels of oil, or 5 barrels of oil per person per year. At the end of 25 years, energy consumption would have doubled from 500 barrels to 1,021 barrels for a composite annual growth rate of 2.89 percent. In 100 years energy consumption would be 9,510, nearly 20 times the original amount—the miracle of double exponential growth.

Figure 1.4 **Per Capita Energy Consumption for the World and for China**

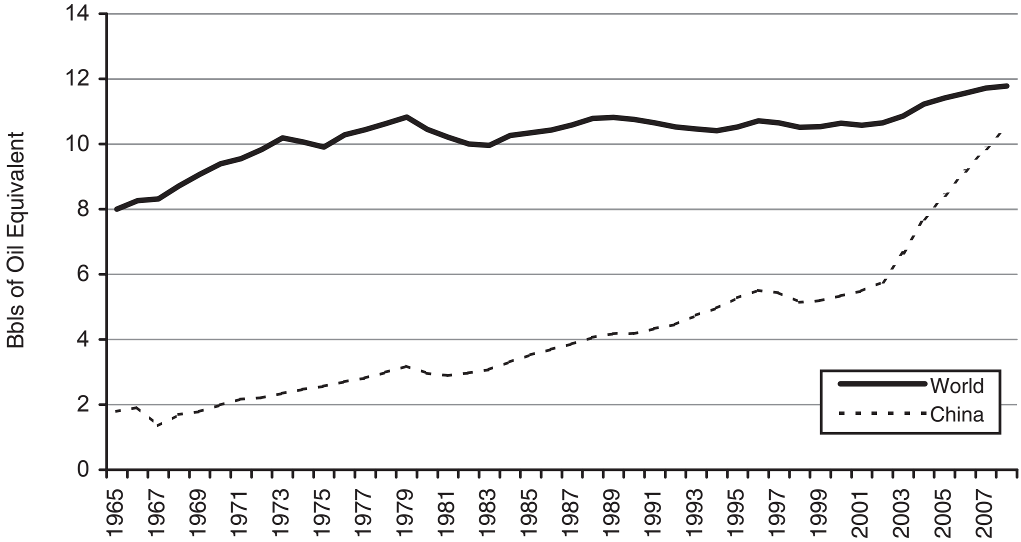


Figure 1.4 shows the per capita consumption of energy for the world and for China from 1965 to 2008. Energy consists of conventional sources of energy (oil, natural gas, coal, nuclear, and hydropower), excluding biomass and alternative energy sources. Energy is expressed in terms of barrels of oil equivalent, which is the equivalent amount of oil that would have to be consumed to release the same amount of energy. A barrel is forty-two gallons, or about three refills of a gasoline tank.

As with China, the world population continues its unremitting climb, with energy consumption rising faster than the population prior to the oil crisis in 1973. High prices in the wake of the crisis slowed energy consumption. The 1973 oil crisis proved that energy consumption is price-sensitive. Per capita energy consumption remained relatively constant until 2002 when it resumed its upward trend primarily caused by the industrialization of China, India, and other nations in Southeast Asia. Much of the steadying of per capita consumption has been caused by a major decline in energy usage in the former Soviet Union after the 1991 fall of communism. Russia has been slowly emerging from its era of economic turmoil. Another factor at work is the decoupling of economic and energy growth in the developed world (United States, Europe, and Japan). Economic activity is less dependent on energy than in the past. Where once 5 percent growth in economic activity was accompanied by a 5 percent growth in energy consumption, now it is 3 percent growth in energy consumption in the United States and even less in Europe. This decoupling of economic and energy growth can be explained by heavy industries, large consumers of energy, moving from the United States and Europe to developing nations in Asia; the rise of the service industry at the expense of manufacturing; and greater energy efficiency in industrial processes, motor vehicles, and home appliances. However, these mitigating factors can no longer compensate for the emergence of India and China as major economic powers. Figure 1.4 shows China, which had significantly lagged in world per capita energy consumption, is rapidly catching up. The double exponential growth curves in China, India, and elsewhere in Asia representing about 40 percent of the world's population have major implications for energy suppliers, consumers, and those responsible for formulating energy policies.

A LESSON IN FISH

Fish is a finite resource that has the property of being sustainable or nonsustainable, depending on the volume of the catch. If it does not seem possible that resources can disappear in a relatively short time as on Easter Island or in one generation as illustrated in Figure 1.1, ponder the world output of fish. It has been transformed from a sustainable to a nonsustainable resource in one generation. Until this generation, the annual fish catch in the world's oceans was less than the reproduction rate, which maintained the fish population. In one generation—our generation—the population of fish, particularly in open-ocean waters, has been severely diminished.

The Grand Banks off Newfoundland is a series of raised submarine plateaus in relatively shallow waters where the cold southbound Labrador Current interacts with the warm northbound Gulf Stream. It is a living paradise for marine life. When John Cabot discovered the Grand Banks 500 years ago, codfish were so plentiful that they were caught by hanging empty wicker baskets over the ship's side.[2] A century later, English fishing skippers reported cod shoals so thick that it was difficult to row a boat through them. Individual fish were six and seven feet long and weighed as much as 200 pounds. Other signs of abundant life were oysters as large as shoes, children collecting ten- to twenty-pound lobsters with hand rakes during low tide, and rivers choked with salmon, herring, squid, and other sea life. Now the cod are gone and the rivers and streams are quiet, essentially devoid of marine life.

Cod fishing became a victim of modern technology. In 1951, a trawler four times larger than a conventional fishing vessel sailed into the waters of the Grand Banks. Large gantry cranes supported cables, winches, and gear to operate huge nets that were let out and then pulled up a stern ramp to dump the fish straight into an onboard fish processing plant. Automated filleting and fishmeal rendering machines made short work of the catch. The trawler was manned by several crews to allow fishing twenty-four hours a day, seven days a week, for weeks on end. Schools of fish were quickly located with fish-finding sonar, greatly enhancing the vessel's productivity. As time went on trawlers increased in number, size, and technological sophistication until they could tow nets with gaping openings 3,500 feet in circumference that swallowed and hauled in 100–200 tons of fish per hour. The trawlers maintained essentially uninterrupted operations with awaiting tenders to transfer crews and fish. By the 1970s, more than 700 high-tech trawlers were in operation around the world, strip-mining the oceans of marine life.

Though it would be convenient to blame this situation on the greed of capitalist-owned fishing companies, over half these trawlers were from the Soviet Union. Both the Soviet Union and capitalist nations, through government subsidies to build and finance trawlers, were heavy promoters of developing and building ever-larger trawlers. These vessels, equipped with longer and wider nets, greater fish-processing capacity, and more accurate fish finders, were built to bring home large quantities of protein to feed a growing population. The outcome was predictable, or at least it should have been, since the trawlers could scoop up fish far faster than they could reproduce. The cod catch peaked in 1968 at 810,000 tons, three times that of 1951 when the first generation of technically advanced fish trawlers made their appearance on the Grand Banks. To combat the precipitous decline that set in after 1968, Canada unilaterally extended its territorial waters from 12 to 200 miles. While other nations were prohibited from entering these waters, Canadian fishermen took advantage of the situation by adding modern fishing vessels to their fleets. The catch fell to 122,000 tons in 1991, forcing the Canadian government to close the Grand Banks to allow fishing stocks to replenish. This devastated the Canadian fishing industry, which in its heyday employed tens of thousands of people.

Much to everyone's surprise, the codfish population never recouped. Dredge-like trawls, designed to harvest marine life from the bottom of the Grand Banks by scouring an area the size of a footfall field, permanently ruined the habitat for juvenile cod. Without a habitat for juveniles, from whence do the adults come? However, one benefit was that the catch of shrimp and crab, the food for juvenile cod, has improved, providing an alternative, though far smaller, source of revenue for fishermen.

In the twenty-first century, sonar technology can locate schools of fish and fine-mesh fishnets tens of miles long can strip the ocean of all life above the size of minnows. The population for some species of fish has dropped to a point where males are finding it difficult to locate females, or vice versa, in the vast ocean spaces. One example is the catch of North Sea cod that has fallen so precipitously in the early 2000s that scientists feared that there might not be enough mature fish left to maintain the population and called for a moratorium on fishing to allow the cod population to recuperate. But Scottish fishermen reacted to this advice with outrage.

Figure 1.5 shows that world marine production (fish caught on the high seas) peaked in 1989 and then declined for a few years. This peak was thought to be the start of a permanent decline, but world marine production recouped and seemingly stabilized.[3] Leveling off of the fish harvest in open ocean waters was not caused by a rising fish population but by greater numbers of even more efficient fishing trawlers harvesting a diminishing resource. Long lines with thousands of baited hooks stretching for eighty miles and drift nets up to forty miles in length, responsible for the death of countless birds and sea mammals, have got to be the ultimate in open-ocean strip-mining.

The number of larger and more efficient trawlers doubled between 1970 and the early 1990s and has grown since then, yet the total catch remained more or less stable. This suggests that the average catch per vessel fell despite the greater capital investment in capacity and technology. Indeed, tons of catch per registered gross ton of fishing vessels fell from 5.4 tons in 1970 to 3.6 tons in 1992, a one-third decline. Lower productivity does not necessarily mean a smaller return on investment if the price of fish escalates enough to compensate for smaller catches. For many nations, fish is an important part of the diet and governments are not willing to cut off this supply of protein, regardless of the long-term consequences (shades of Easter Island). Another reason why so many governments are reluctant to put effective international controls on fishing is to protect their investment in the form of government subsidies for trawler acquisition and financing. This is what is going on in oil. More money is being spent on wells to tap diminishing reserves in more difficult environments, but profitability can be maintained despite higher capital and operating costs and lower output by a compensating increase in price.

Unlike the Easter Islanders, we have not stood idly by in the face of depleting fish resources in the world's oceans. Many maritime nations have enacted programs to preserve the fish population within their territorial waters by regulating the timing, size, and volume of fish and other marine life that can be caught. As an example, marine biologists survey the egg population of herring in territorial Alaskan waters from the air because the untold billions of herring eggs make the normally dark waters milky white. From their observations they can estimate the herring population and, through a government regulatory agency, mandate the area and timing of the herring harvest. The harvest of herring is controlled on the basis of preserving a resource to ensure its long-term viability rather than depleting a resource in the quest for short-term profits. The volume of the herring harvest is not regulated, only the allowable area and the permitted time for harvesting. Licenses control the number of fishing boats and the nature of the technology being employed. If it is felt that the volume harvested is too great and endangering the population, more stringent restrictions on area and timing and licensing are enacted. If the population of herring is rising, then the restrictions are relaxed.

Regulating fishing in a nation's territorial waters is practiced throughout much of the world. But it is a palliative, not a cure, as fish are free to migrate in and out of territorial waters. Little headway has been made in passing an international convention on open-ocean fishing that would position fishing as a sustaining activity rather than depleting a natural resource. The politically correct-sounding International Convention on Fishing and Conservation of the Living Resources of the High Seas went into force in 1966, but apparently its provisions are either not effective or not effectively enforced to sustain the long-term viability of commercial sea life in international waters.

Those who maintain that nothing can be done to protect open-ocean fish resources should look at the international regulation of the whaling industry. The International Convention for the Regulation of Whaling was proposed in 1946 and came into force in 1948 when the requisite number of nations had ratified it. The Whaling Commission meets annually and determines protected and unprotected species; open and closed seasons and waters; designation of sanctuary areas, size limits, and the maximum catch for each species; and permissible methods, types, and specifications of whaling gear. The commission also controls the methods of measurement and maintains the requisite statistical and biological records, and places tough restrictions on location and season to ensure that the catch does not exceed certain limits. The whale population for various species is monitored to see if any adjustments have to be made to relax or strengthen restrictions on whaling activities.

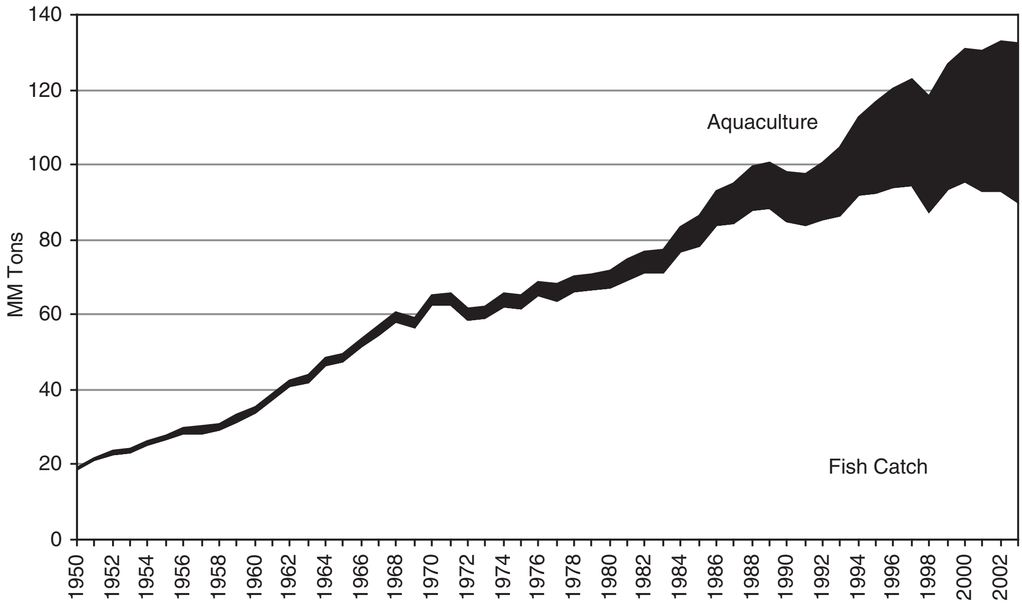
The international convention on whaling has been responsible for preventing the extinction of various species of whales and also promoting their recovery despite criticism of the Japanese whaling fleet for allegedly violating convention rules. This successful convention not only had a highly desirable environmental impact on sea life, but could also serve as a model for the administration and enforcement of an international convention on open-ocean fishing. However, in all fairness, trying to monitor and control fishing fleets numbering in the millions scattered throughout the world through a system of licenses and quotas would, for all practical purposes, be impossible. The task of the Whaling Commission is made easier by virtue of there being relatively few whaling fleets restricted to only a handful of nations. However, if the world's maritime nations had the collective will to assume the responsibility for monitoring fishing vessels calling on ports within their jurisdiction, or outlawing those practices that essentially strip-mine the ocean of fish, then it might be possible to reverse the further diminishment of a valuable resource.

FROM HUNTING TO FARMING

Figure 1.5 also shows a successful countermeasure to overexploiting a natural resource. The rising price of fish has created a new industry: fish farming—agricultural enterprises dedicated to raising fish. Fish pens in protected waters in Norway and Canada supply much of the salmon found in the world's marketplace. Decades ago, farmers in the southern United States could not make a living growing and selling grain until they discovered that they could make a living by throwing grain into a pond and selling the catfish. Trout, tilapia, and shrimp are also farmed. Tilapia originated in Africa and was farmed in ponds and rice paddies in Asia for generations; now tilapia is farmed throughout the world. As seen in Figure 1.5, the tonnage of aquaculture production, or fish farming, has grown thirteen-fold in thirty years, providing nearly one-third of total fish consumption.

To be sure, there is opposition to aquaculture, or fish farming, including the potential environmental impact of thousands of tons of waste collected under fish pens, the biological treatments necessary to prevent the spread of disease in crowded fish pens, plus the consequences of fish escaping from an artificial to a natural environment. On the other hand, the human population

Figure 1.5 **Fish Harvest**



needs to be fed, and providing fish from fish farms rather than depleting the world's open-ocean resources seems to have an inherent advantage that should not be ignored.

ENERGY DEPLETION

The point of all this is that a trend line indicating that a resource will be exhausted in thirty years need not happen. Unlike fish, which could recuperate in numbers if allowed to, fossil fuels such as coal, oil, and natural gas cannot replenish themselves (ignoring for now speculation about the possible nonorganic origin of natural gas from deep within the earth). With regard to energy, sustainable sources of energy (biofuels, solar, and wind) would be akin to fish farming. The viability of sustainable sources of energy can be assured by a high price on a diminishing source of nonsustainable (fossil) fuel.

We have already set the precedent of having an international convention to preserve a natural resource. International conventions can be successful in preserving natural resources (whales) or unsuccessful (open-ocean fish). As with whales and, perhaps, someday with fish, some form of cooperative action may be necessary to preserve another worldwide resource—energy—if only to prevent the inevitable result of doing nothing: having a planetary-scale Easter Island blowout.

NOTES

1. Population statistics are from the U.S. Census Bureau Web site, and energy statistics are from the *BP Statistical Review of World Energy* (London: British Petroleum, 2009).
2. Colin Woodard, "A Run on the Banks," *E-Magazine* (March–April 2001).
3. Food and Agricultural Organization of the United Nations (FAO), as listed on the World Resources Institute Web site www.earthtrends.org.