3

Moving Up the Food Chain Efficiently

Throughout most of our 4 million years as a distinct species we lived as hunter-gatherers. The share of our diets that came from hunting or gathering varied with geographic location, skills, and the season of the year. During the northern hemisphere winter, when there was little to gather, we depended heavily on hunting for our survival. This long history as hunter-gatherers left us with an appetite for animal protein, one that continues to shape diets today.

In every country where incomes have risen, this appetite for meat, eggs, and seafood has generated an enormous growth in animal protein consumption. The form the animal protein takes depends heavily on geography. Countries that are land-rich with vast grasslands depend heavily on beef—the United States, Brazil, Argentina, Australia, and Russia—or on mutton, as in Australia and Kazakhstan. Countries that are more densely populated and lack extensive grazing lands have historically relied much more on pork. Among these are Germany, Poland, and China. Densely populated countries with long shorelines, such as Japan and Norway, have turned to the oceans for their animal protein.[1]

While we typically focus on the food requirements

generated by population growth and the pressure this puts on the earth's land and water resources, moving up the food chain also adds to the pressure. The challenge is to do so as efficiently as possible, minimizing additional demands on land and water. Encouragingly, new approaches to the production of livestock, poultry, and fish are raising the efficiency with which grain is converted into animal protein.

Up the Food Chain

For those living at subsistence level, 60 percent or more of calories typically come from a single starchy food staple such as rice, wheat, or corn. Diversifying this diet is everywhere a high personal priority as incomes rise. One of the first additions people make is animal protein in some form—meat, milk, eggs, and fish.[2]

Since 1950, world meat production has climbed from 44 million to 253 million tons, more than a fivefold jump. Except for 1959, it has risen every year during this period, becoming one of the world's most predictable economic trends. (See Figure 3–1.) Worldwide, the average person consumed 41 kilograms of meat in 2003, more than double the figure a half-century ago.[3]

Comparing grain use per person in India and the United States gives us an idea of how much grain it takes to move up the food chain. In a low-income country like India—where annual grain production falls well short of 200 kilograms per person, or roughly 1 pound a day—nearly all grain must be eaten directly to satisfy basic food energy needs. Little can be converted into animal protein. Not surprisingly, the consumption of most livestock products in India, especially meat where religious restrictions also apply, is rather low. Milk, egg, and poultry consumption, however, are beginning to rise, particularly among India's expanding middle class.[4]

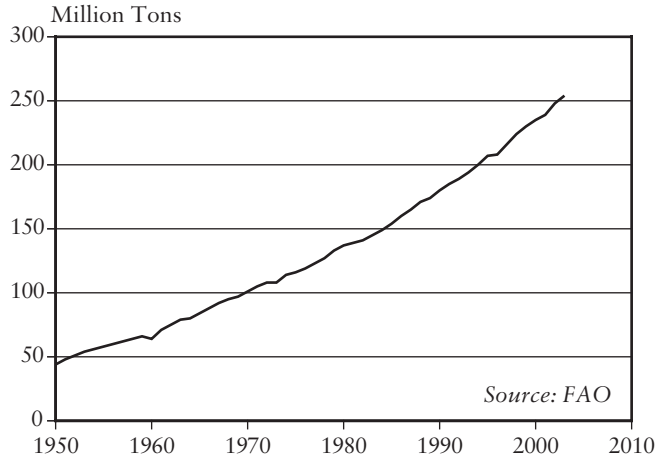

Figure 3–1. *World Meat Production, 1950–2003*

The average American, in contrast, consumes roughly 800 kilograms of grain per year, four fifths or more of it indirectly in the form of meat, milk, eggs, and farmed fish. Thus the grain consumption, direct and indirect, of an affluent American is easily four times that of the typical Indian.[5]

Ironically, the healthiest people in the world are not those who live very low or very high on the food chain but those who occupy an intermediate position. Italians, eating less than 400 kilograms of grain per person annually, have a longer life expectancy than either Indians or Americans. This is all the more remarkable because U.S. expenditures on health care per person are much higher than those in Italy. Italians benefit from what is commonly described as the Mediterranean diet, considered by many to be the world's healthiest.[6]

People in some countries live high on the food chain but use relatively little grain to feed animals; Argentina and Brazil, for instance, depend heavily on grass-fed beef.

Japanese also live high on the food chain, but use only moderate amounts of feedgrains because their protein intake is dominated by seafood from oceanic fisheries.[7]

Shifting Protein Sources

The composition of world meat production has changed dramatically over the last half-century or so. From 1950 until 1978, beef and pork vied for the lead. (See Figure 3–2.) Then the world meat consumption pattern began to change as economic reforms adopted in China in 1978 led to a dramatic climb in pork production, pushing it far ahead of beef worldwide.[8]

In an effort to minimize waste, village families in China have a long-standing tradition of keeping a pig, which is fed all the kitchen and table waste. When the pig matures, it is butchered and eaten and replaced with another small, recently weaned, pig. Even today, four fifths of China's pork production takes place at the family level.[9]

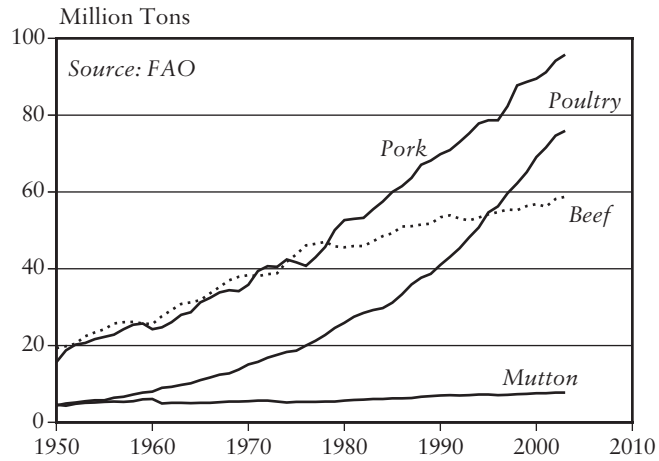

Figure 3–2. *World Meat Production by Type, 1950–2003*

With China's 1.3 billion people clamoring for more pork, production there climbed from 9 million tons in 1978, the year of the economic reforms, to 46 million tons in 2003. U.S. pork production rose only from 6 million to 9 million tons during the same period, and pork consumption per person in China overtook that in the United States. Perhaps even more impressive, half of the world's pork is now eaten in China.[10]

In 1950, when beef and pork dominated world meat consumption, poultry production was quite low, roughly the same as mutton. From mid-century onward, however, poultry production gathered momentum, overtaking beef in 1996. Advances in the efficiency of poultry production had dropped the price to the point where more and more people could afford it. In the United States—where a half-century ago chicken was something special, usually served only at Sunday dinner—its low price now makes chicken the meat of choice for everyday consumption.[11]

With overgrazing widespread, additional beef production now comes largely from putting more cattle in feedlots for a longer period of time. Thus the changing composition of our diets reflects the widely varying efficiency with which cattle, pigs, chickens, and, increasingly, fish convert grain into protein. A steer in a feedlot requires 7 kilograms of grain for each kilogram of weight gain. For pork, each kilogram of additional live weight requires about 3.5 kilograms. For poultry, it is just over 2. For catfish in the United States and carp in China and India, it is 1–2 kilograms of feed per kilogram of additional weight gain.[12]

Between 1990 and 2003, growth in beef production averaged less than 1 percent a year. Pork, meanwhile, expanded at 2.5 percent annually, eggs at nearly 4 percent, and poultry at 5 percent. Aquacultural output, which sets the gold standard in the efficiency of feed conversion into protein, expanded by nearly 10 percent a year, climbing from 13 million tons in 1990 to 40 million tons in 2002. (See Table 3–1.)[13]

Historically, as the demand for seafood increased with rising incomes, countries turned to the oceans. As population pressure built up, for example, beginning a century or so ago, Japan needed nearly all its arable land to produce rice, leaving almost none for producing feed for livestock and poultry. So the country started relying more on fish for animal protein and now consumes 10 million tons of seafood per year. But with oceanic fisheries being pushed to their limits, there are few opportunities for countries developing appetites for animal protein to switch to eating fish in the same way. For example, if China's per capita consumption of seafood from oceanic fisheries reached the Japanese level, the country would need 100 million tons of seafood—more than the world catch.[14]

Table 3–1. *Annual Growth in World Animal Protein Production, by Source, 1990–2003*

Source	1990	2003	Annual Growth
	(million tons)		(percent)
Beef	53	59	0.8
Pork	70	96	2.5
Mutton	10	12	1.6
Poultry	41	76	4.9
Eggs	38	61	3.7
Oceanic Fish Catch	85	93[1]	0.8
Aquacultural Output	13	40[1]	9.7

[1]Figures for 2002.

Source: See endnote 13.

So although China is a leading claimant on oceanic fisheries, with a catch of 16 million tons per year, it has turned to fish farming to satisfy most of its fast-growing seafood needs and is leading the world into the aquaculture era. China's aquacultural output, mainly carp and shellfish, totals 28 million tons. With incomes now rising in densely populated Asia, other countries are following China's lead. Among them are India, Thailand, and Viet Nam. Viet Nam, for example, devised a plan in 2001 of developing 700,000 hectares of land in the Mekong Delta for aquaculture, with the goal of producing 1.7 million tons of fish and shrimp by 2005. It now appears likely to exceed this goal.[15]

Over the last 15 years, aquaculture has thus emerged as a major source of animal protein. Driven by the high efficiency with which omnivorous species, such as carp, tilapia, and catfish, convert grain into animal protein, world aquacultural output nearly tripled between 1990 and 2002. It will likely overtake beef production worldwide by 2010.[16]

As the consumption of animal protein has grown, the share of the world grain harvest used for feed has remained constant at roughly 37 percent for two decades. Of the world's three leading grains—rice, wheat, and corn—which together account for nearly 90 percent of the grain harvest, rice is grown almost entirely as a food crop. Wheat is largely a food crop, but one sixth of the wheat harvest is fed to livestock and poultry. In contrast, the world's huge corn harvest is consumed largely as feed. In recent years, the addition of a protein supplement (typically soybean meal) to feed rations has boosted the efficiency of feed conversion into animal protein. This stabilized the share of the world grain harvest used for feed even while meat, milk, and egg consumption per person were climbing.[17]

Oceans and Rangelands

During much of the last half-century, the growth in demand for animal protein was satisfied by the rising output of two natural systems: oceanic fisheries and rangelands. Between 1950 and 1990, the oceanic fish catch climbed from 19 million to 85 million tons, a fivefold gain. (See Figure 3–3.) During this period, seafood consumption per person nearly doubled, climbing from 8 to 15 kilograms.[18]

This was the golden age of oceanic fisheries. Never before had the world seen such growth in an animal protein source. It grew rapidly as fishing technologies evolved that helped fishers bring in their catch more efficiently and as refrigerated processing ships began to accompany fishing fleets, enabling them to operate in distant waters.

Unfortunately, the human appetite for seafood is outgrowing the sustainable yield of oceanic fisheries. Today

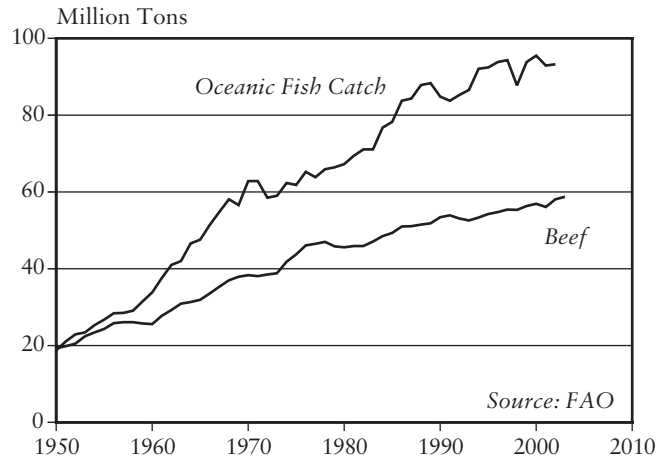

Figure 3–3. *World Oceanic Fish Catch and Beef Production, 1950–2003*

70 percent of fisheries are being fished at or beyond their sustainable capacity. As a result, many are in decline and some have collapsed. In some fisheries, the breeding stocks have been mostly destroyed. A 2003 landmark study by a Canadian-German science team, published in *Nature*, concluded that 90 percent of the large predatory fish in the oceans had disappeared over the last 50 years.[19]

This ambitious, 10-year assessment drew on data from all the world's major fisheries. Ransom Myers, a fisheries biologist at Canada's Dalhousie University and lead scientist in this study, says, "From giant blue marlin to mighty blue fin tuna, from tropical groupers to Antarctic cod, industrial fishing has scoured the global ocean. There is no blue frontier left."[20]

Fisheries are collapsing throughout the world. The fabled cod fishery of Canada failed in the early 1990s. Those off the coast of New England were not far behind. And in Europe, cod fisheries are in decline, approaching a free fall. Like the Canadian cod fishery, the European fisheries may have been depleted to the point of no return.[21]

Myers goes on to say, "Since 1950, with the onset of industrialized fisheries, we have rapidly reduced the resource base to less than 10 percent—not just in some areas, not just for some stocks, but for entire communities of these large fish species from the tropics to the poles." In contrast to the rapid rise in seafood consumption per person during the last century, the world's still-growing population is now facing a substantial decline in seafood catch per person.[22]

Rangelands, like the oceans, are also essentially natural systems. Located mostly in semiarid regions too dry to sustain agriculture, they are vast, covering roughly twice the area planted to crops.[23]

Perhaps 180 million of the world's people depend

entirely on livestock for their livelihood. Most of these are in the pastoral communities of Africa, the Middle East, Central Asia, Mongolia, and northern and western China. As these populations grew, so did their livestock populations. Environmentally, nearly all these pastoral societies are in trouble. Since rangelands are typically owned in common, there is no immediate reason for individual families to limit the number of cattle, sheep, or goats. The result is widespread overgrazing, desertification, personal hardship, and slower growth in livestock production.[24]

World beef production climbed from 20 million tons in 1950 to nearly 60 million tons in 2003. But after doubling between 1950 and 1975, growth has become progressively slower, dropping to under 1 percent a year since 1990. Just as oceanic fisheries are being overfished, the world's rangelands are being overgrazed. As a result, the grasses on which livestock forage are slowly deteriorating.[25]

As vegetation disappears, the soil begins to blow. At first dust storms remove the finer particles of soil. Once these have largely blown away, sand storms become the prevailing measure of degradation. As the sand begins to drift, it forms sand dunes; these begin to encroach on farmers' land, making both grazing and farming untenable.

The world has reached the end of an era with both oceanic fisheries and rangelands. Human demands for seafood, beef, and mutton have surpassed the sustainable yield of these systems. With these two natural systems reaching their limits, future growth in animal protein production will have to come largely from feeding. Producing the feedstuffs, principally corn and soybeans, will put more pressure on the earth's land and water resources—pressure that is already unsustainable in some countries. At this point, the incorporation of soybean meal into livestock rations to boost sharply the efficiency with which grain is converted into animal protein is indispensable.

The Soybean Factor

When we think of soybeans in our daily diet, it is typically as tofu, veggie burgers, or other meat substitutes. But most of the world's fast-growing soybean harvest is consumed indirectly in the beef, pork, poultry, milk, eggs, and farmed fish that we eat. Although not a visible part of our diets, the incorporation of soybean meal into feed rations has revolutionized the world feed industry, greatly increasing the efficiency with which grain is converted into animal protein.[26]

In 2004, the world's farmers produced 223 million tons of soybeans, 1 ton for every 9 tons of grain they produced. Of this, some 15 million tons were consumed as tofu or meat substitutes. The remaining 208 million tons were crushed in order to extract 33 million tons of soybean oil, separating it from the more highly valued meal. Soybean oil dominates the world vegetable oil economy, supplying much of the oil used for cooking and to dress salads. Soybean oil production exceeds that of all the other table oils combined—olive, safflower, canola, sunflower, and palm oil.[27]

The 143 million tons of soybean meal that remains after the oil is extracted is fed to cattle, pigs, chicken, and fish, enriching their diets with high-quality protein. Experience in feeding shows that combining soybean meal with grain, in roughly one part meal to four parts grain, dramatically boosts the efficiency with which grain is converted into animal protein, sometimes nearly doubling it.[28]

The world's three largest meat producers—China, the United States, and Brazil—now all rely heavily on soybean meal as a protein supplement in feed rations. The United States has long used soybean meal to upgrade livestock and poultry feed. As early as 1964, 8 percent of feed rations consisted of soybean meal. Over most of the last decade, the meal content of U.S. feeds has fluctuated between 17 and 19 percent.[29]

For Brazil, the shift to soybean meal as a protein supplement began in the late 1980s. From 1986 to 1997, the soymeal share of feed rations jumped from 2 percent to 21 percent. In China, the realization that feed use efficiency could be dramatically boosted with soymeal was translated into reality some six years later. Between 1991 and 2002, the soymeal component of feed jumped from 2 percent to 20 percent. For fish, whose protein demands are particularly high, China incorporated some 5 million tons of soymeal into the 16 million tons of grain-based fish feed used in 2003.[30]

The experience of these three countries simply indicates that the same principles of animal nutrition apply everywhere. The ratio of soybean meal to corn in the feed mix varies somewhat according to the price relationship between the two. Where corn is cheap, as in the United States, the corn share of the feed mix tends to be slightly higher. In Brazil, which has an economic advantage in soybean production, the soy component is higher.[31]

As world grain production was tripling from 1950 to 2004, soybean production was expanding thirteenfold. The growth in this protein source, most of it consumed indirectly in various animal products, is a surrogate for rising affluence, one that measures movement up the food chain.[32]

The soybean was domesticated in central China some 5,000 years ago and made its way to the United States in 1804, when Thomas Jefferson was President. For a century and a half the soybean was grown mostly as a curiosity crop in home gardens. Most farmers outside of China did not even know what a soybean looked like. But after World War II, production exploded as the consumption of livestock and poultry products climbed in North America and Europe.[33]

By 1978, the area planted to soybeans in the United States had eclipsed that planted to wheat. In some recent years, the U.S. harvested area of soybeans has exceeded that of corn, making it the country's most widely planted crop. In the United States, where soybean production is now five times that in China, the soybean has found an ecological and economic niche far larger than in its country of origin.[34]

U.S. soybeans are grown mostly in the Corn Belt, often in rotation with corn. The soybean, a nitrogen-fixing legume, and corn, which has a ravenous appetite for nitrogen, fit together nicely on the same piece of land in alternate years. In fact, if the Corn Belt were being named today, it would be called the Corn/Soybean Belt.[35]

Another chapter in the soybean saga has been unfolding over the past three decades in Latin America. After the collapse in 1972 of the Peruvian anchovy fishery—which accounted for a fifth of the world fish catch and supplied much of the protein meal used in livestock and poultry foods at that time—some countries in Latin America saw an opportunity to produce soybeans. As a result, both Brazil and Argentina began to expand soybean production, slowly at first and then, during the 1990s, at breakneck speed. As of 2004, soybean production exceeds that of all grains combined in both countries. Brazil now exports more soybeans than the United States does. And within the next few years Brazil is likely to overtake the United States in production as well.[36]

While production was increasing thirteenfold over the last half-century, soybean yields have almost tripled, which means that the area in soybeans has increased some fourfold. In contrast to grains, where the growth in output has come largely from raising yields, growth in the harvest of the land-hungry soybean has come more from area expansion.[37]

As a result, in a world with limited cropland resources, the soybean has been expanding partly at the expense of grain. Nonetheless, this expansion so greatly increases the efficiency of grain used for feed that it reduces the cropland area used to produce feedgrains and soybeans together.[38]

New Protein Models

Mounting pressure on the earth's land and water resources to produce livestock, poultry, and fish feed has led to the evolution of some promising new animal protein production models, one of which is milk production in India. Since 1970, India's milk production has increased more than fourfold, jumping from 21 million to 87 million tons. In 1997, India overtook the United States in dairy production, making it the world's leading producer of milk and other dairy products. (See Figure 3–4.)[39]

The spark for this explosive growth came in 1965 when an enterprising young Indian, Dr. Vargese Kurien, organized the National Dairy Development Board, an umbrella organization of dairy cooperatives. A coop's principal purpose was to market the milk from tiny herds that typically averaged two to three cows each. It was these dairy cooperatives that provided the link between the growing appetite for dairy products and the millions of village families who had only a few cows and a small marketable surplus.[40]

Creating the market for milk spurred the fourfold growth in output. In a country where protein shortages stunt the growth of so many children, expanding the milk supply from less than half a cup per person a day 25 years ago to more than a cup represents a major advance.[41]

What is new here is that India has built the world's largest dairy industry almost entirely on roughage—wheat straw, rice straw, corn stalks, and grass collected

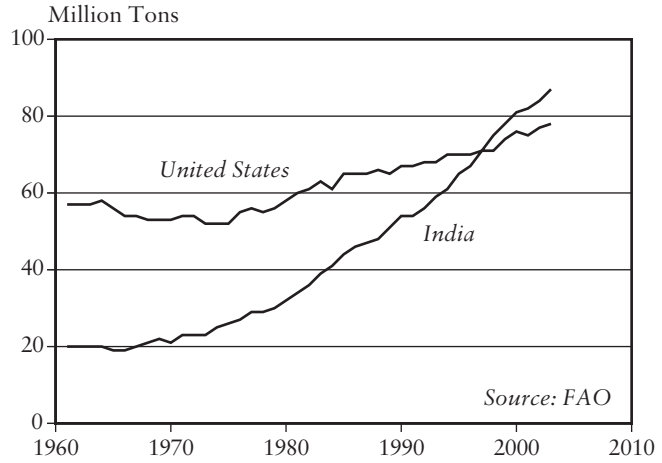

Figure 3–4. *Milk Production in India and the United States, 1961–2003*

from the roadside. Cows are often stall-fed with crop residues or grass gathered daily and brought to them.[42]

A second new protein production model, which also relies on ruminants, is one that has evolved in China, principally in four provinces of central Eastern China—Hebei, Shangdong, Henan, and Anhui—where double cropping of winter wheat and corn is common. Once the winter wheat matures and ripens in early summer, it must be harvested quickly and the seedbed prepared to plant the corn. The straw that is removed from the land in preparing the seedbed as well as the cornstalks left after the corn harvest in late fall are fed to cattle. Although these crop residues are often used by the villagers as fuel for cooking, they are shifting to other sources of energy for cooking, which lets them keep the straw and cornstalks for feed. By supplementing this roughage with small amounts of nitrogen, typically in the form of urea, the microflora in the complex four-stomach digestive system of cattle can convert roughage efficiently into animal protein.[43]

This practice enables these four crop-producing provinces to produce much more beef than the vast grazing provinces in the northwest do. This central eastern region of China, dubbed the Beef Belt by Chinese officials, is producing large quantities of animal protein using only roughage. The use of crop residues to produce milk in India and beef in China means farmers are reaping a second harvest from the original crop.[44]

Another promising new animal protein production model has also evolved in China, this one in the aquacultural sector. China has evolved a carp polyculture production system in which four species of carp are grown together. One species feeds on phytoplankton. One feeds on zooplankton. A third feeds on grass. And the fourth is a bottom feeder. These four species thus form a small ecosystem, with each filling a particular niche. This multi-species system, which converts feed into flesh with remarkable efficiency, yielded some 13 million tons of carp in 2002.[45]

While poultry production has grown rapidly in China over the last two decades, it has been dwarfed by the phenomenal growth of aquaculture. (See Figure 3–5.) Today aquacultural output in China—at 28 million tons—is double that of poultry, making it the first country where aquaculture has emerged as a leading source of animal protein. The great economic and environmental attraction of this system is the efficiency with which it produces animal protein.[46]

Although these three new protein models have evolved in India and China, both densely populated nations, they may find a place in other parts of the world as population pressures intensify and as people seek new ways to convert plant products into animal protein.

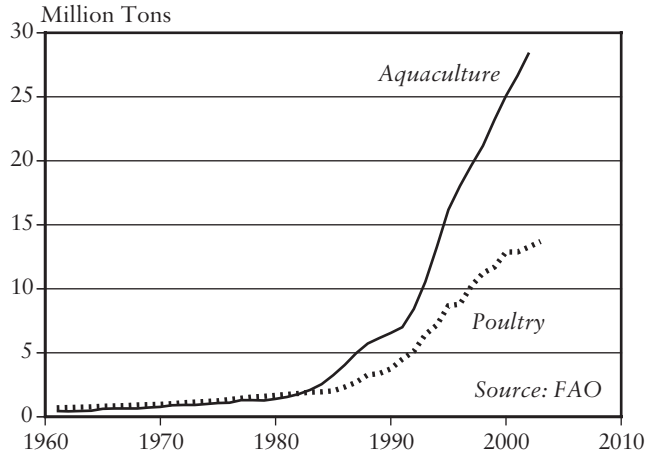

Figure 3–5. *Aquacultural and Poultry Production in China, 1961–2003*

The world desperately needs more new protein production techniques such as these. A half-century ago, when there were only 2.5 billion people in the world, virtually everyone wanted to move up the food chain. Today there may be close to 5 billion people wanting more animal protein in their diet. The overall demand for meat is growing at twice the rate of population; the demand for eggs is growing nearly three times as fast; and growth in the demand for fish—both from the oceans and from fish farms—is also outpacing that of population. Against this backdrop of growing world demand, our ingenuity in producing animal protein in ever-larger quantities and ever more efficiently is going to be challenged to the utmost.[47]

While the world has had many years of experience in feeding an additional 70 million or more people each year, it has no experience with some 5 billion people wanting to move up the food chain at the same time. For

a sense of what this translates into, consider what has happened in China since the economic reforms in 1978. As the fastest-growing economy in the world since 1980, China has in effect telescoped history, showing how diets change when incomes rise rapidly over an extended period.[48]

As recently as 1978, meat consumption was low in China, consisting mostly of modest amounts of pork. Since then, consumption of pork, beef, poultry, and mutton has climbed. In 2003 people in China ate some 71 million tons of meat, close to twice as much as Americans ate. China has decisively displaced the United States, long number one in meat consumption. (See Figure 3–6.)[49]

As incomes rise in other developing countries, people will also want to increase their consumption of animal protein. Considering the demand this will place on the

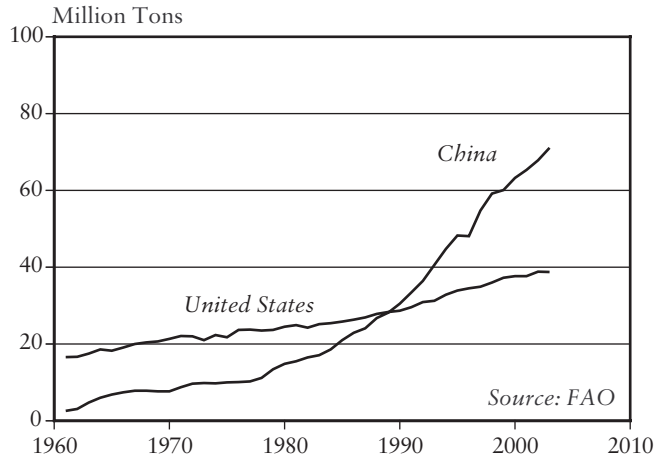

Figure 3–6. *Meat Production in China and the United States, 1961–2003*

earth's land and water resources, along with the more traditional demand from population growth, provides a better sense of the future pressures on the earth. If world grain supplies tighten in the years ahead, the competition for this basic resource between those living high on the food chain and those on the bottom rungs of the economic ladder will become both more visible and a possible source of tension within and among societies.

Data for figures and additional information can be found at www.earth-policy.org/Books/Out/index.htm.