

Population Growth, Increases in Agricultural Production and Trends in Food Prices

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Abstract

During the second half of the twentieth century, human numbers and food demand grew at an unprecedented pace, yet food supplies increased even faster. Demographic expansion is now slackening, due to dramatic reductions in human fertility in Asia, Latin America, and other parts of the world. However, demand for edible goods will continue to go up, mainly because improved living standards are causing per-capita consumption to rise. To avoid mounting food scarcity, the geographic expansion of agriculture at the expense of forests and other habitats, or both, effective investment in research and development, especially in agricultural biotechnology, is needed so that per-hectare yields can continue increasing.

Since the middle of the twentieth century, food demand has increased at an unprecedented pace. Most of the growth has been demographic, with human numbers rising from 2.47 billion in 1950 to 6.06 billion in 2000 and 6.70 billion today. But living standards have also improved in recent decades – especially in Asia, where more than half the human population resides. As a result, what we eat has changed substantially. For example, fruits and vegetables are now a more important part of the diet than historically. In addition, consumption of livestock products has increased, which has driven up the demand for corn and other feed grains eaten by cattle, pigs, chickens, and other livestock.

However, contrary to predictions of the pessimists, rising numbers and growing appetites have not led to an unmeasured expansion of farmland and pasture. Instead, agricultural yields have increased, thanks to the

Green Revolution and other technological advances. For the world as a whole, per-hectare output of cereals, which account for more than half the food people eat if the grain fed to livestock is factored in, had risen by the late 1990s to 3.0 metric tons, which was double the average yield in the early 1960s (Southgate, Graham, and Tweeten 2007, p. 58). Primarily because of yield growth, food supplies increased faster than food demand throughout this period.

Market trends constitute irrefutable proof that food grew less scarce, not more so, during the second half of the twentieth century. Prices of corn, rice, and other staple grains were 75 percent lower in the middle 1980s than in 1950. Real prices then stayed at low levels for two decades. Most of the three-quarters decline occurred during the Green Revolution, which began in the middle 1960s and lasted for more than 15 years.

The benefits of cheaper food have been far-reaching and profound. Certainly, billions of people around the world who try to subsist on a dollar or two a day have been able to eat better. Also, cheaper food has enabled people to consume more non-food items, thereby stimulating the economic diversification that is intrinsic to economic development. Furthermore, households have been able to save more, which has accelerated investment and economic growth.

However, commodity prices have recently been rising again – and this may continue for some time (though the very high prices of 2008 were probably driven in large part by the excessive supply of money and speculative purchases). One reason is that demand for food is continuing to grow, in large part because of improved living standards and diets. In light of demand growth, greater support for technological improvement, which has been the main reason why food supplies have increased faster than demand, is absolutely essential. Sadly, this support has been sorely lacking for many years. Barring a renewed

commitment to technological improvement, including the widest possible use of agricultural biotechnology, there is little chance that food prices will return to the low levels which were taken for granted just a few years ago. As a result, food insecurity could well worsen south of the Sahara and in other impoverished settings.

Demand trends

To this day, the thinking of many people about changes over time in food demand derives entirely from a simplistic understanding of the demographic analysis of Thomas Robert Malthus (1798/1963). According to this view, total consumption of edible goods is directly proportional to human numbers, which rise exponentially whenever food supplies exceed what people require for bare subsistence.

This view neglects the increases in consumption that coincide with a sustained improvement in living standards, which Malthus acknowledged could happen but did not examine in detail. Also unappreciated is the deceleration in population growth that has happened in recent decades. Understanding this deceleration requires a little knowledge of demographic transition, to which I now turn.

Demographic transition is a feature of modern times, something that began in a few parts of Europe during the 1700s and was under way throughout the world by the middle of the twentieth century. Before the transition, yearly birth rates differed little from yearly death rates and both rates were very high by today's standards, equal to 3½ to 5 percent. Well into the transition, birth and death rates are in line with each other again, though closer to 1 percent per annum.¹

The entire process got under way because death rates fall. That is, the beginning of the transition was marked by an "escape from hunger and premature death," to quote the title of a recent book by Nobel-laureate economist Robert Fogel (2004). With birth rates not declining as rapidly as death rates from pre-transition levels, natural increase was inevitable. As Nicholas Eberstadt, of the American Enterprise Institute, puts it: "Rapid population growth commenced not because human beings suddenly started breeding like rabbits but rather because they stopped dying like flies" (2007, p. 7).

As death rates have fallen, people have chosen to have fewer children. Driving this decline in total fertility rates (i.e., the number of births per woman) has been a number of interrelated trends: improved living standards, urbanization, and a declining infant mortality

(which diminishes a household's need to have an "extra" child or two in order to end up with the desired number of offspring). Nothing affects child-bearing more than female economic empowerment, as indicated by educational attainment and workforce participation. This empowerment raises the opportunity costs of the time that women spend bearing and raising children.

Evidence abounds that a revolution in human fertility has occurred in recent decades. As is widely known, the number of births per woman fell below the replacement rate (about 2.1) in China several years ago and currently stands at 1.8. However, many developing nations have comparable fertility rates, even without anything resembling China's one-child-per-family policy. Among these nations are Chile (2.0 births per woman), Thailand (1.8), Tunisia (2.0), and Vietnam (2.1). The number of births per woman in Eastern Europe and many parts of the Former Soviet Union has fallen to, or even below, numbers on the other side of the old Iron Curtain. There are 1.3 births per woman in Russia and the Czech Republic – indistinguishable from total fertility rates in Germany, Italy, and Spain. Sub-Saharan Africa is the only part of the world where total fertility rates have not declined very much from pre-transition levels; on average, women in the region bear 5.2 children (World Bank 2008).

Even after human fertility has fallen to or below the replacement level, births continue to exceed deaths for a while. This is because the containment of infectious diseases which occurs at the onset of demographic transition creates demographic momentum. To be specific, infants and small children, who in a former age would have succumbed to one communicable illness or another, instead survive. Fifteen or more years later, total fertility rates have declined, but births remain numerous because there are more young people of child-bearing age. As long as human fertility is sustained at the replacement level, demographic momentum gradually dissipates. As this happens, natural increase dwindles to zero.

Demographic trends in Mexico (World Bank 2008) illustrate this general pattern. By the early 1960s, mortality had abated significantly, yet the country's fertility rate (6.9) was close to the pre-transition norm. Death rates remained at very low levels during the next two decades and the number of births per woman fell dramatically, to 4.4 in the early 1980s. Yet the Mexican population grew from 37 to 69 million, largely because of gathering demographic momentum. Today, human numbers, which have reached 105 million, continue to go up, albeit at a much slower pace. Natural increase is not an outcome of elevated fertility. With women only bearing 2.2 children

Table 1: **Increase in food demand, 2000 to 2050**

<i>Scenario</i>	<i>Change</i>
Human population equals 7.87 billion in 2050 and annual growth in per-capita consumption averages 0.4 percent.	59 percent
Human population equals 9.32 billion in 2050 and annual growth in per-capita consumption averages:	
0.2 percent	70
0.3 percent	79
0.4 percent	88
Human population equals 10.93 billion in 2050 and annual growth in per-capita consumption averages 0.2 percent.	99

Source: Southgate, Graham, and Tweeten (2007), p. 33.

on average, births exceed deaths almost entirely because of demographic momentum.

In affluent nations and in quite a few developing countries, the demographic transition is further along than in Mexico. Elsewhere, including in Sub-Saharan Africa, the process is at an earlier stage. However, demographic realities immediately to the south of the United States are broadly representative of realities in the developing world as a whole, which accounted for 80 percent of the increase in the human population during the twentieth century. To summarize, natural increase, which is being driven more and more by demographic momentum as human fertility continues to decline, is decelerating. There is little prospect of the human population doubling in four or five decades, as happened during the second half of the twentieth century (UNEP 2009a).

As population growth decelerates, changes in per-capita consumption resulting from income growth are having a correspondingly greater impact on trends in food demand. Drawing on demographic projections issued by the U.N. Population Division (UNPD) in 2001 and making different assumptions about annual increases in per-capita consumption, Southgate, Graham, and Tweeten (2007) have estimated demand growth during the first half of the twenty-first century. The results are reported in Table 1.

A median forecast of the increase in food demand occurring between 2000 and 2050 is obtained by supposing that human numbers will grow from 6.06 billion to 9.32 billion during this period and that per-capita consumption will rise by 0.3 percent per annum, which is consistent with long-term trends (UNDP 2009b). Note that, with these assumptions, food demand will be four-fifths higher in 2050 than in 2000 even with population growth of 50 percent.

Needless to say, something less than the median

forecast is obtained if per-capita consumption grows a little more slowly. Likewise, demand will be at a higher level in 2050 if human diets improve at a faster pace. To obtain a lower-bound forecast of food demand in 2050, it is appropriate to combine the lowest of the three UNPD demographic projections (7.87 billion) with 0.4 percent annual growth in per-capita consumption. This is because a sharp deceleration in population growth is likely to be observed only if living standards (and therefore female economic empowerment, urbanization, and other factors associated with low fertility) improve dramatically, in which case average food consumption will also go up rapidly. Under this scenario, the global population will reach a peak around the middle of this century and then begin a gradual decline. Yet if this happens, which many people concerned about population growth would regard as ideal, demand growth during the first half of this century will still approach 60 percent.

Food demand will go up more if there is a larger increase in human numbers. As indicated in Table 1, such an increase would probably coincide with slower improvement in human diets. If this happens, food demand in 2050 will be twice the level observed at the turn of the twenty-first century. This represents an upper bound on projected demand.

Trends in supply and prices

As noted earlier, increases in population and food demand were unprecedented during the second half of the twentieth century, when our numbers more than doubled and incomes rose noticeably in Asia and other parts of the developing world. Yet food grew less scarce, not more so, because supplies were increasing at a faster pace.

For some commodities, supply growth was largely a

consequence of increases in cultivated area. For example, plantings of soybeans and other oil crops grew by 94 percent between 1961 and 2001. Likewise, land used to produce fruits and vegetables at the turn of the twenty-first century was nearly double the area used for this purpose four decades earlier. These increases in land use, which coincided with yield growth, were needed to keep up with burgeoning demands for oil crops, fruits, and vegetables, which were in turn an outcome of dietary diversification and other changes resulting from improved living standards (Southgate, Graham, and Tweeten 2007, pp. 53–54).

In contrast, the area planted to cereals in 2001 – 676 million hectares, which represented three-fifths of the 1,114 million hectares planted to non-industrial crops (e.g., cotton and sugar) throughout the world – was less than 5 percent greater than the 648 million hectares used for cereal production in 1961, when 923 million hectares were used to produce non-industrial crops (Southgate, Graham, and Tweeten 2007, pp. 53–54).

Increases in agricultural land use, generally, and in the area sown to grain, specifically, were greatly exceeded by growth in human numbers and food demand. Yet output went up even faster, almost entirely because of yield improvement. In 1961, the global average yield of cereals was a little less than 1.5 tons per hectare – comparable to the level maintained in the United States from the middle 1860s, when the U.S. Department of Agriculture began collecting and publishing nationwide data, through the middle 1930s, when U.S. farmers began raising yields by using inputs such as hybrid seeds and chemical fertilizer. During the next four decades, production per hectare went up steadily. As mentioned in the introduction, the average cereal yield for the world as a whole rose above 3.0 tons at the end of the twentieth century.

For more than fifteen years beginning in the middle 1960s, improvements in cereal yields were concentrated in south and southeast Asia, thanks to the Green Revolution. This advance, which was made possible by agricultural research and testing carried out over many years, thanks to support provided initially by the Rockefeller and Ford Foundations and later by donor agencies such as the World Bank and U.S. Agency for International Development, resulted in new varieties of rice and wheat. These new varieties produced more grain than traditional strains when fertilizer and irrigation water were applied to farm fields (Dalrymple 1985).

The Green Revolution has been closely scrutinized. As it was occurring and even for a few years afterward, concerns were expressed about the impacts on small farmers, who would have suffered economic losses had

they not adopted improved crop varieties and had commodity prices fallen because larger producers were doing so. But this did not occur. To the contrary, small farmers made use of Green Revolution technology about as readily as other growers did. Furthermore, the technological advance was enormously beneficial for landless people in the countryside, who as a rule comprise the poorest segment of the rural population. This is because they found it easier to find employment on the farms of other people and because they could purchase food at lower prices (Dalrymple 1985; Southgate, Graham, and Tweeten 2007, pp. 59–60).

The environmental consequences of the Green Revolution have been criticized. For example, some of the fertilizer and other chemical inputs that farmers have applied to their fields have found their way into rivers, lakes, and streams, thereby causing pollution. In addition, irrigation development has in some places led to the depletion of hydrologic resources. While they do not deny these impacts, Southgate, Graham and Tweeten (2007) point out that much environmental damage is mainly a consequence of misguided policies. The subsidized prices at which agricultural chemicals have been sold, to accelerate the Green Revolution, have caused these inputs to be wasted and misallocated. By the same token, pricing water at a fraction of the cost of delivering this resource to farm fields has created widespread inefficiencies and environmental damage (p. 111).

There is an entirely different complaint about the Green Revolution, which is that it has had very little impact on Sub-Saharan Africa. However, it is difficult to quarrel with the decision four or five decades ago to focus agricultural improvements on staple grains grown under irrigated conditions in Asia. The population of that continent comprised an even larger portion of the human race then than it does today. Moreover, it was the poorest part of the world during the 1960s. Sub-Saharan Africa, where much of the population subsists on root crops, plantains, and other things grown under rain-fed conditions, may be in greater need of a Green Revolution today. But increasing irrigated yields of rice and other staples of Asian diets was considered by many to be the top priority forty years ago.

The varying impacts of the Green Revolution in different parts of the world are indicated in Table 2. Per-capita food production rose by nearly three-quarters in Asia between the early 1960s and the turn of the twenty-first century. Though not as dramatic, the relative improvement in South America was still sizable. In contrast, per-capita production in Africa was 6 percent lower in 1981 than it had been twenty years earlier and

Table 2: **Changes in per-capita food production since the early 1960s**

	As of 1981, %	As of 2001, %
Africa	-6	-10
Asia	+14	+73
South America	+15	+44
World	+12	+26

Source: Southgate, Graham, and Tweeten (2007), p. 67.

the decline continued during the next two decades. The latter continent was the major exception of the global trend during the second half of the twentieth century toward greater availability.

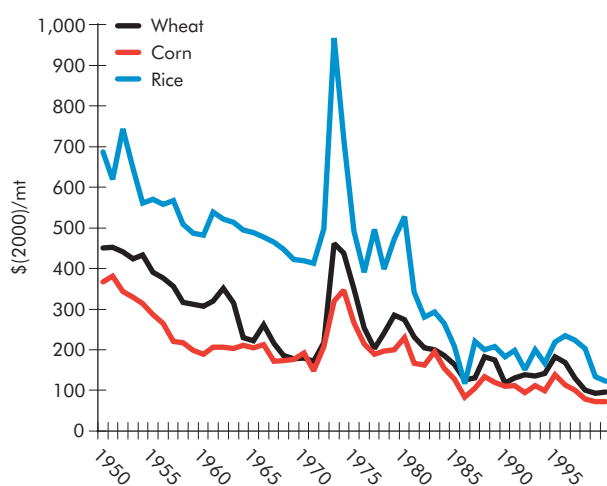
The price adjustments that occurred as grain supplies grew faster than food demand are reported in Figure 1. Much to the benefit of Paul Ehrlich, the Club of Rome, and others who, three or four decades ago, sold a lot of books by predicting imminent food shortages, economic collapse, and related ills, prices of agricultural commodities spiked in the 1970s. However, this was not a result of fundamental shifts in demand and supply. Instead, events in the Soviet Union were largely to blame. Reluctant to cut consumers' supplies of food in the face of poor grain harvests and the expanded feeding of livestock, communist authorities abandoned their long-standing policy against importing grain and increased purchases substantially in international markets. Demand also went up because of increased lending to Latin America and other developing regions, which used a portion of borrowed monies to import more food.

Demand shocks caused prices of wheat, rice, and corn to rise by 100 percent or more in the middle 1970s. However, market values did not stay high for long. After the early 1980s, real prices were back on a long-term declining path. As shown in Figure 1, inflation-adjusted values of staple grains were 75 percent lower in the mid-1980s than in 1950, with most of the decline occurring after the Green Revolution began in the middle 1960s.

Shortly before the recent run-up in prices of agricultural commodities, Southgate, Graham, and Tweeten (2007) assessed the prospects for continuation of the trends reported in Figure 1. They assumed that agricultural land use would not vary appreciably during the twenty-first century and that the yield growth registered since the early 1960s would continue through 2050. They also supposed that any gap of 1 percentage point between demand growth and supply growth would result in a price change of 2 percent, because neither consumption nor production is very sensitive to price changes (p. 87). The results of combining these assumptions with the demand forecasts in Table 1 are presented in Table 3.

If these results are any guide, there is little prospect that real prices of agricultural commodities will continue falling at the pace observed during the second half of the twentieth century. A modest decline – 26 percent over five decades – will occur if the human population rises to 7.87 billion in 2050, even if annual growth in per-capita consumption accelerates from 0.3 to 0.4 percent (Scenario 1). If per-capita consumption continues to increase by 0.3 percent per annum and population rises to 9.32 billion, then inflation-adjusted prices in the middle of this century will be 14 percent greater than in 2000 (Scenario 2). Yet another possibility is faster demographic expansion and slower growth in per-capita consumption. Under these circumstances, real prices in 2050 will be more than 50 percent above their level at the turn of the twenty-first century (Scenario 3).

Southgate, Graham, and Tweeten (2007) caution that their projections depend on continued growth in yields, which is not guaranteed by any means. Particularly worrying, they note, is that support for agricultural research and development, which grew dramatically during the 1960s, 1970s, and 1980s and which made the

Figure 1 **Real prices of rice, wheat, and corn, 1950 to 2000**

Source: Southgate, Graham, and Tweeten (2007), p. 84

Table 3: **Changes in real food prices, 2000 to 2050**

Scenario	Change in real prices, %
(1) Human population equals 7.87 billion in 2050 and annual growth in per-capita consumption averages 0.4 percent.	-26
(2) Human population equals 9.32 billion in 2050 and annual growth in per-capita consumption averages 0.3 percent	+14
(3) Human population equals 10.93 billion in 2050 and annual growth in per-capita consumption averages 0.2 percent.	+54

Green Revolution possible, has not increased in recent years (pp. 64–65). Pardey, Alston and Jones (2008) document that private-sector spending agricultural biotechnology has gone up, almost entirely in the United States and other rich nations. Meanwhile, budgets for agriculture's science and technology base have actually declined in many parts of the world since the 1980s. Since many years typically elapse between scientists' discoveries in the laboratory and farmers' adoption of new technologies made possible by those discoveries, continued growth in agricultural yields has been jeopardized because of declining support for research and development – and opposition to biotech-derived foods.

Alleviating food scarcity

For the first time since the 1970s, prices of agricultural commodities rose by more than 100 percent in just a few months in late 2007 and the first half of 2008. The market value of soybeans, for example, was under \$6/bushel in early 2007 – little changed from what it was two years earlier. A year or so later, soybean prices climbed above \$12/bushel.

Much of this increase was a consequence of monetary expansion in the United States. Taking a comprehensive view, one can say that the monetization of fiscal deficits in the country, which a few years ago caused real estate values to inflate, resulted in 2007 and 2008 in higher prices of food, oil, and other primary commodities.

In addition to macroeconomic imbalances, subsidies to biofuels also contributed to higher prices of agricultural commodities. A much-cited case in point is the conversion of corn into ethanol in the United States. Since the US accounts for a very large share of global exports, the diversion of one-fourth or more of the country's crop has driven up corn prices, not to mention market values of substitute goods. In addition, enhanced competition for land and other agricultural resources has led to higher commodity prices across the board (Schnepf 2008).

Trade restrictions adopted by at least three dozen

exporting nations in the developing world also adversely affected output and increased prices. These restrictions – such as the taxes that the Argentine government imposes on foreign commodity sales – cause resources to be misallocated and international prices to rise excessively.

No doubt, food prices would not have risen as high if monetary authorities in the United States had counteracted inflation more vigorously, if there had been no subsidies for biofuels development, and if free trade were embraced universally, by exporters and importers alike. But as emphasized in this paper, long-term trends in global commodity markets will depend mainly on relative growth in demand and supply.

There is nothing new about rapid demand growth. To repeat, human numbers increased at an unprecedented rate between 1950 and 2000 and diets improved markedly in many parts of the world. Moreover, there is no reason for food supplies to fall behind food demand, provided that all avenues of technological improvement are fully exploited. In part, this involves taking full advantage of agricultural biotechnology.² But a reversal of the trend in recent decades toward ever-lower support for agricultural research and development is also necessary. At the Rome summit, Secretary General Ban advocated a \$30 billion in annual funding.

In the global food economy, recent history yields clear lessons. Agricultural production has more than kept pace with food demand in the past. It can certainly do so again, provided that governments do not stand in the way of free trade and technological progress.

Notes

1. Demographers emphasize that the absence of natural increase (defined as births minus deaths) does not mean that the transition has come to an end. Instead, post-transition equilibrium has not been reached unless the distribution of the population among different age cohorts has stabilized. As Lee (2003) points out, no such stabilization can be observed in any part of the world, including the dozens of countries where there is little or no natural increase. Thus, demographic transition continues to be a ubiquitous phenomenon.
2. Something that governments must do to foster technological improvement in agriculture is not to impose needless restrictions on the genetically-modified (GM) products created thanks to agricultural biotechnology. Sadly, encumbrances of this sort are still being put in place. Just recently, for example, the German government banned GM corn that has been engineered to resist pests (BBC, 14 April 2009). Since corn growers who do not use this variety must instead apply more pesticides, the environmental consequences of this restriction are undoubtedly negative. So are the production impacts.

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