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Forces Reshaping World Agriculture

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Abstract

This paper examines many of the forces reshaping world agriculture. Among these forces are increased trade liberalization, agricultural research and development, and new movements in developing countries. Worldwide agricultural production is likely to become more competitive as a result of increased trade liberalization through the World Trade Organization and regional and bilateral free trade agreements. Countries can become more competitive through agricultural research and development. As a result of research and development, total agricultural production has increased significantly across the world over the last several decades. Agricultural research has also led to the development of many new, non-food uses for agricultural products. New movements in developing countries include the substantial increases in agricultural production in Brazil and Argentina, and increases in consumption in China and other countries.

Keywords: globalization, research and development, productivity, biofuels, Brazil, food demand

Highlights

A number of factors are likely to reshape the future of world agriculture. Trade liberalization, farm policy, agricultural research, changes in consumer demand, new uses for agricultural products, new developments in developing countries, and production increases in Brazil and Argentina are factors that have major impacts on world agriculture.

Increased trade liberalization, through the World Trade Organization (WTO) negotiations and numerous bilateral and regional free trade agreements, will likely make worldwide agricultural production more competitive. As a result, product specialization within countries will increase based on resource endowments. Free trade agreements affect trade through trade creation, trade diversion, and income effects. If a WTO agreement is reached, U.S. producers could benefit from increased market access, the elimination of the EU's export subsidies, and greater harmonization between the United States and the EU in trade-distorting domestic support. However, the agreement would also have a significant effect on U.S. agricultural policy. With the current U.S. farm bill set to expire in 2007, a new farm bill will be constructed that could contain fewer subsidy payments due to WTO rules and federal budget constraints.

To improve competitiveness, countries can increase productivity by investing in agricultural research and development. Agricultural research has led to higher yielding crop varieties, better livestock breeding practices, more effective fertilizers and pesticides, and better farm management practices. As a result of these advancements, agricultural productivity has increased in a number of countries around the world. The emergence of biotechnology could especially have a significant impact on productivity worldwide. Total agricultural production has been increasing significantly across the world over the last several decades, and production has been increasing the greatest in percentage terms in developing countries. Total factor productivity for U.S. agriculture has continually been increasing, although the growth rate has slowed in recent years. While technological advances appear to initially benefit producers by leading to higher yields, lower costs, and increased productivity, consumers ultimately benefit from lower real food prices. This can be demonstrated by the decline in real commodity prices over time.

Research has also led to the development of many non-food uses for agricultural products, increasing the demand for and value of agricultural commodities. The wide variety of industrial products that can be produced from agricultural commodities includes biofuels such as ethanol and biodiesel, and numerous bio-based products. The greatest increase in the use of corn recently has been for ethanol. New ethanol and biodiesel plants are continually being built. This trend, which is likely to continue for the near future, has been largely driven by government policy to promote domestically-produced renewable energy. The cellulose from biomass can also be used to produce ethanol. Switchgrass, in particular, has significant potential as an ethanol feedstock, and other potential feedstocks include corn stover, wheat straw, and fast-growing trees.

Brazil and Argentina have become increasingly competitive in the world market as production in these two countries has increased dramatically in recent years. The largest increases have been for soybeans. Brazil still has the potential for much greater increases due to available land that could be brought into production, creating increased competition for the United States in the world market. There are some factors limiting expansion in Brazil, however, including the transportation system. The devaluation of the currencies in Brazil and Argentina have had a positive effect on exports from those countries.

As China, India, and other developing countries continue to grow, their demand for food will increase, and rising incomes in these countries could result in shifts in demand. This could result in significant changes in world trade flows. Data on food consumption over the last few decades show that there have been changes in demand for different agricultural products in developed and developing countries.

In developed countries, per capita consumption of vegetable oils has increased considerably in recent years. As incomes continue to grow in those countries, consumer demand may increase for high quality and specialty products, which could have an effect on production systems. Consumption of animal products is now growing the fastest in developing countries, and vegetable oil consumption is also increasing significantly in those countries. If per capita income in developing countries continues to grow, per capita consumption of animal products and vegetable oils are likely to continue increasing, while per capita consumption of rice and wheat may have peaked. Increased demand for meat in developing countries could also have a significant influence on the demand for animal feeds such as corn and soybean meal.

Forces Reshaping World Agriculture

Jeremy W. Mattson and Won W. Koo*

INTRODUCTION

Throughout history, agriculture has experienced numerous changes. This is expected to continue as a number of factors are likely to reshape the future of world agriculture. Trade liberalization and farm policy have a substantial influence on agricultural production and trade across the world. Bilateral and regional free trade agreements, World Trade Organization (WTO) negotiations, and future U.S. farm bills will likely have a significant effect on U.S. and world agriculture. Increased trade liberalization results in increased competition, and to be competitive in the world market, countries must invest in research and development. Agricultural research has led to increased productivity across the world. Advancements from the Green Revolution led to increased yields and productivity, and worldwide agricultural production continues to increase despite a limit to available land. These technological advancements continue today and will likely persist into the future. Biotechnology is prominent among current and future technological advancements. Research and development has also led to additional uses for agricultural products, such as bio-based products and biofuels.

Changes in consumer demand are also affecting the shape of agriculture. Much of the increased productivity gain will be needed to meet the growing demand for food caused by an increasing population. Increases in consumer income and changes in preferences are affecting the types of food products demanded. Finally, changes in developing countries, such as substantial production increases in Brazil and Argentina and increases in demand for agricultural products in China and other countries, are reshaping world trade flows.

This paper examines many of these forces reshaping world agriculture. In the next section of the paper, agricultural policy and trade issues are discussed, including regional and bilateral free trade agreements, WTO negotiations, and the effects of trade liberalization. In section three, the impacts of agricultural research and development are discussed. Increases in production, yields, and productivity for both developed and developing countries are examined, and many of the technological advances that led to these increases are discussed. The importance of agricultural research and the question "who benefits from the technological advancements?" is also discussed, as well as the development of industrial uses of agricultural products. In section four, new movements in developing countries are examined. Brazil and Argentina have experienced significant production increases in recent years, and the possibility that these two countries could be the future breadbasket of the world is investigated. Increased consumption in China and other developing countries is also examined. The last section contains a summary and conclusions.

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GLOBALIZATION THROUGH THE WTO AND REGIONAL FREE TRADE AGREEMENTS

Government policies and international trade rules have a substantial impact on agricultural production and trade around the world. WTO negotiations, bilateral and multilateral free trade agreements (FTAs), and changes in government policy will influence agriculture worldwide. Increased trade results in increased competition and more product specialization based on resource endowments. Some sectors benefit from free trade movements, while others may be harmed.

Free trade agreements affect trade through trade creation, trade diversion, and income effects. Trade flows may increase due to the elimination or reduction of tariffs or other trade barriers. Trade creation occurs when trade volume between two countries increases as a result of the displacement of domestic production. Domestic producers of the product being replaced with imports are harmed. When trade creation occurs, however, resources are reallocated toward more efficient uses, which increases returns on investment and improves the overall economic well-being of the member countries (Economic Research Service (ERS) 1998). Trade diversion occurs when increases in trade with one country displace trade with third-party countries. Trade directly harms other countries outside the agreement. There are also dynamic results such as the income effect. Free trade agreements generally lead to increased income in the member countries, which positively affects imports.

The United States started an FTA with Canada in 1989, and the North American Free Trade Agreement (NAFTA), which includes Canada and Mexico, was implemented in 1994. Under NAFTA, U.S. agricultural imports and exports with these two countries have both increased substantially. More recently, the United States began an FTA with Chile in 2004 and Australia in 2005, and the Central American Free Trade Agreement (CAFTA) - an agreement between the United States and five Central American countries and the Dominican Republic - began in 2006. The United States is also negotiating trade agreements with Korea, Thailand, the Andean countries of South America, the South African Customs Union, Morocco, and potentially others. There are also a number of trade agreements across the world which the United States are outsiders to, and which put U.S. exporters at a disadvantage.

Mattson et al. (2004) found that the U.S. - Australia FTA could result in small losses for the U.S. agricultural sector, as Australian exports of beef and dairy products to the United States could increase, but the quota increases under the 18-year phase-in period of the agreement would likely have minimal impact on the U.S. beef industry. CAFTA may have a positive impact on U.S. exports of some commodities, but it would also result in increased U.S. sugar imports. Sugar imports could also increase from Mexico under NAFTA and from other sugar-producing countries if new agreements are signed. The cumulative impact of these import increases could result in a significant reduction of U.S. sugar prices and production (Koo et al. 2003).

Plans for the Free Trade Area of the Americas (FTAA), a regional free trade agreement encompassing 34 western hemisphere countries, have stalled. If revived, the FTAA could have a significant influence on trade flows. The agreement may be beneficial for the U.S. agricultural sector because it will expand market opportunities for agricultural goods. Mattson and Koo

(2002) found that U.S. agricultural exports would increase more than imports under an FTAA. Agricultural tariffs in western hemisphere countries are higher than those in the United States. The FTAA could also help U.S. exporters that are presently outsiders in many of the current free trade areas in the hemisphere. U.S. exports of meat products, corn, and rice could increase significantly under the FTAA (Mattson and Koo 2003).

Some commodities, however, could experience trade losses under the FTAA. For example, this agreement could have major implications for the sugar industry. A significant amount of sugar is produced in Latin American countries, and the FTAA could give U.S. consumers access to inexpensive imported sugar from low-cost producers such as Brazil. Imports of fruit and juice could also increase considerably under the FTAA. Increased competition from soybean producers in Argentina and Brazil is another important issue that needs to be studied.

While many bilateral and regional free trade agreements are coming into effect between countries across the world, causing trade creation and trade diversion effects, the WTO negotiations are attempting to lower trade barriers worldwide and set new trade rules for its nearly 150 members. The 1986–1994 Uruguay Round significantly changed the trade practices related to agricultural goods. Agricultural trade is now firmly managed within the multilateral trading system under the WTO. The Agriculture Agreement, together with individual countries' commitments to reduce export subsidies, domestic support, and import barriers on agricultural products, formed a significant first step toward reforming agricultural trade. Under the current Doha Round, there are three major areas of negotiation: market access, export competition, and domestic support. Substantial reductions in tariffs, domestic support, and export subsidies are prominent issues in the negotiations. There is also some support for the agreement to include a number of issues such as food safety, mandatory labeling, the environment, rural development, animal welfare, and geographical indications.

The WTO members reached an agreement July 31, 2004, on the framework for the final phase of the Doha Round. With regard to domestic support, the framework agreement calls for each member's total trade-distorting support to be cut by 20 percent from currently allowed levels in the first year of implementation, with additional reductions to take place in subsequent years according to a yet-to-be-determined tiered formula. Under the pillar of export competition, the framework agreement calls for the elimination of export subsidies as well as export credits with repayment periods beyond 180 days. Greater market access will occur, under the agreement, through the reduction of tariffs. Negotiating the details of the agreement, however, has proven to be difficult. The lack of significant progress in 2005 and early 2006 has led many to believe that a deal may not be agreed upon in the near future.

If an agreement is reached, U.S. producers could benefit from increased market access, the elimination of the European Union's (EU) export subsidies, and greater harmonization between the United States and the EU in trade-distorting domestic support. However, the agreement would also have a significant effect on U.S. agricultural policy (Mattson and Koo 2006). With the current U.S. farm bill set to expire in 2007, a new farm bill will be constructed that could contain fewer subsidy payments due to WTO rules and federal budget constraints. The U.S. proposal in the WTO negotiations would reduce the U.S. spending limit on amber box, or trade-distorting, subsidies from $19.1 billion per year to $7.6 billion. This would require a significant cut in current programs, including marketing loan deficiency payments. Other countries are proposing even greater cuts. Maintaining the current farm program structure would require significant reductions in loan rates, target prices, and milk and sugar price support levels. Alternatively, more comprehensive reform could be enacted, which could include a shift in payments to non-trade-distorting green box subsidies. One alternative is to introduce a revenue insurance program and increase direct payments.

RESEARCH AND DEVELOPMENT TO IMPROVE COMPETITIVENESS

As a result of increased globalization, agricultural production will become more competitive. To improve competitiveness, countries increase productivity by investing in agricultural research and development. Production can grow through increased use of land, increased use of other inputs, or increased productivity. Productivity captures growth in production not accounted for by growth in inputs. It is often measured by total factor productivity (TFP), which is the ratio of total outputs to total inputs. Technological change has a significant influence on productivity.

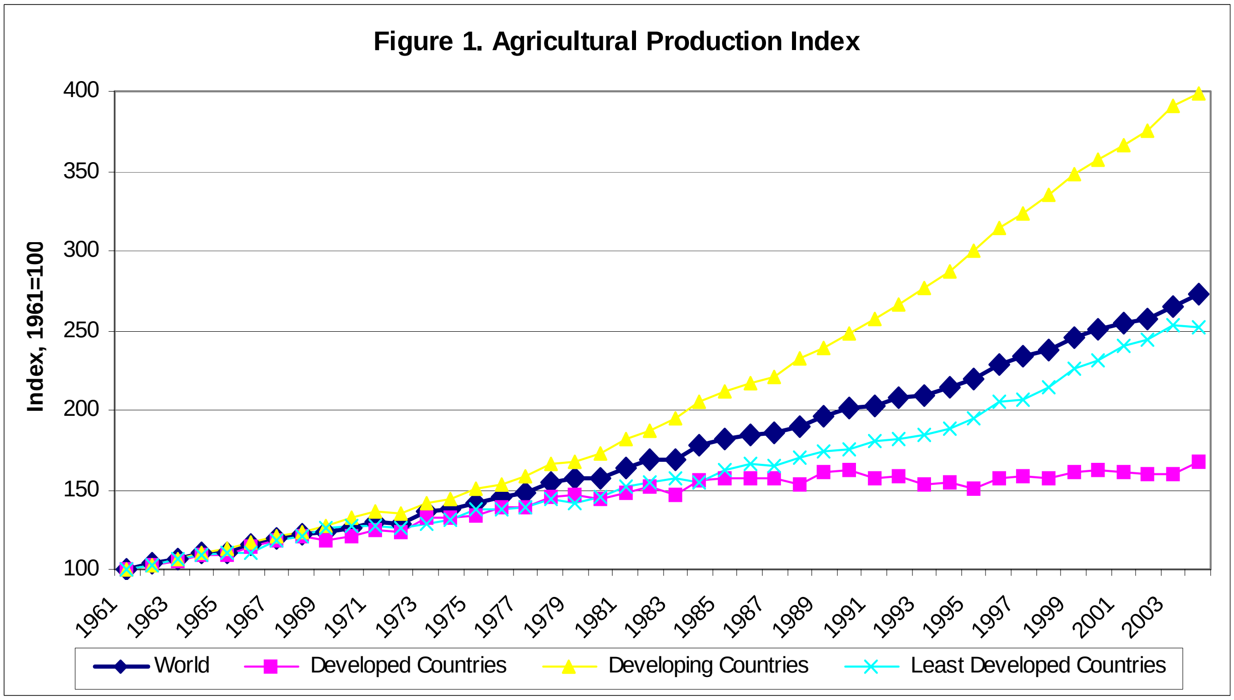
Factors affecting productivity include research and development (R&D), extension, education, infrastructure, and government programs (Ahearn et al. 1998). Agricultural research has led to higher yielding crop varieties, better livestock breeding practices, more effective fertilizers and pesticides, and better farm management practices. Many of the initial advancements led to the Green Revolution, which began in the mid-20th century.

Agricultural research across the world has continued to grow. Global public agricultural research expenditures (measured in 1993 international dollars) increased from $11.8 billion in 1976 to $21.7 billion in 1995, but growth in spending for many parts of the world slowed in the 1990s (Pardey and Beintema 2001). The largest increases in public research spending over the 1976-1995 period were in developing countries. Public spending on research in developing countries surpassed that in developed countries by the 1990s, but the growth in research was not uniform among these countries; China and India have experienced the greatest increases in public research, while research in sub-Saharan African countries has been stagnant (Pardey and Beintema 2001). In the United States, public sector funding in real terms for research has stagnated over the last few decades – public expenditures equaled $3.2 billion in both 1978 and 1998 (Klotz-Ingram 2002). Private sector research in the United States, on the other hand, has increased substantially over this period and now surpasses public research. By 1995, spending on private sector research had equaled spending on public sector research in developed countries across the world. On the other hand, private sector research in developing countries remained insignificant, as 95 percent of research in these countries was funded by the public sector.

Worldwide Agricultural Production Increases

The Green Revolution produced improved crop varieties and better agricultural techniques. Hybrid seeds were developed, machinery sizes increased, and the use of fertilizers, herbicides, pesticides, and irrigation intensified. These advancements led to increased yields and increased productivity in a number of countries around the world, including many developing countries. Pardey and Beintema (2001) note that the world used about 1.4 billion hectares of land for crops in 1961 and only about 1.5 billion hectares in 1998 to grow twice the amount of grain and oilseeds. Animal production also increased due to improved livestock breeding, improved genetics, and advancements in animal nutrition. Some countries did not benefit as greatly, though: there were few gain in many of the staple crops of Africa such as yams, cassava, sorghum, and cowpeas (Caswell 2004).

Largely due to technological advancements, total agricultural production has been increasing significantly across the world over the last several decades. Production has been increasing the greatest in percentage terms in developing countries. Figure 1 shows the agricultural production index for developed and developing countries, least developed countries, and the world total from 1961 to 2004, where 1961=100.[1] Agricultural production in developing countries increased 300 percent over this period. In comparison, production in developed countries increased 68 percent, total world production increased 173 percent, and production in the least-developed countries increased 152 percent. The largest percentage increases have been in East Asia,



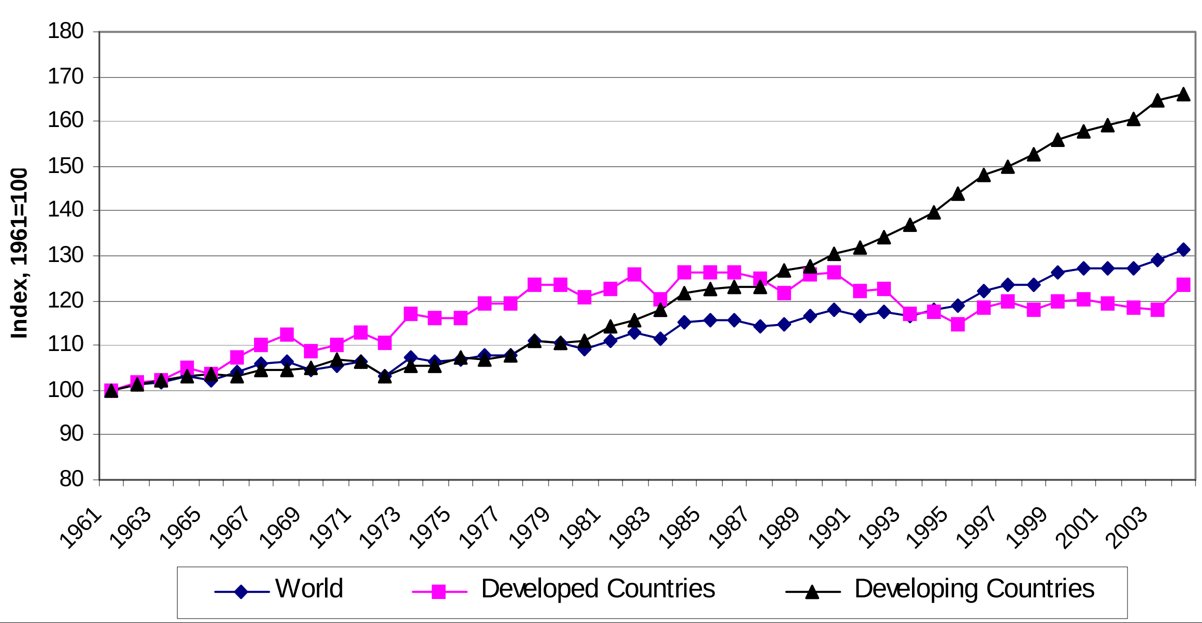
Source: FAOSTAT

[1]See Appendix 1 for a listing of countries classified as developed, developing, and least developed, as defined by the FAOSTAT database.

specifically China, and there have also been significant increases in South America, the Middle East, South Asia, and Mexico. The smallest percentage increases have been in Europe and the Caribbean.

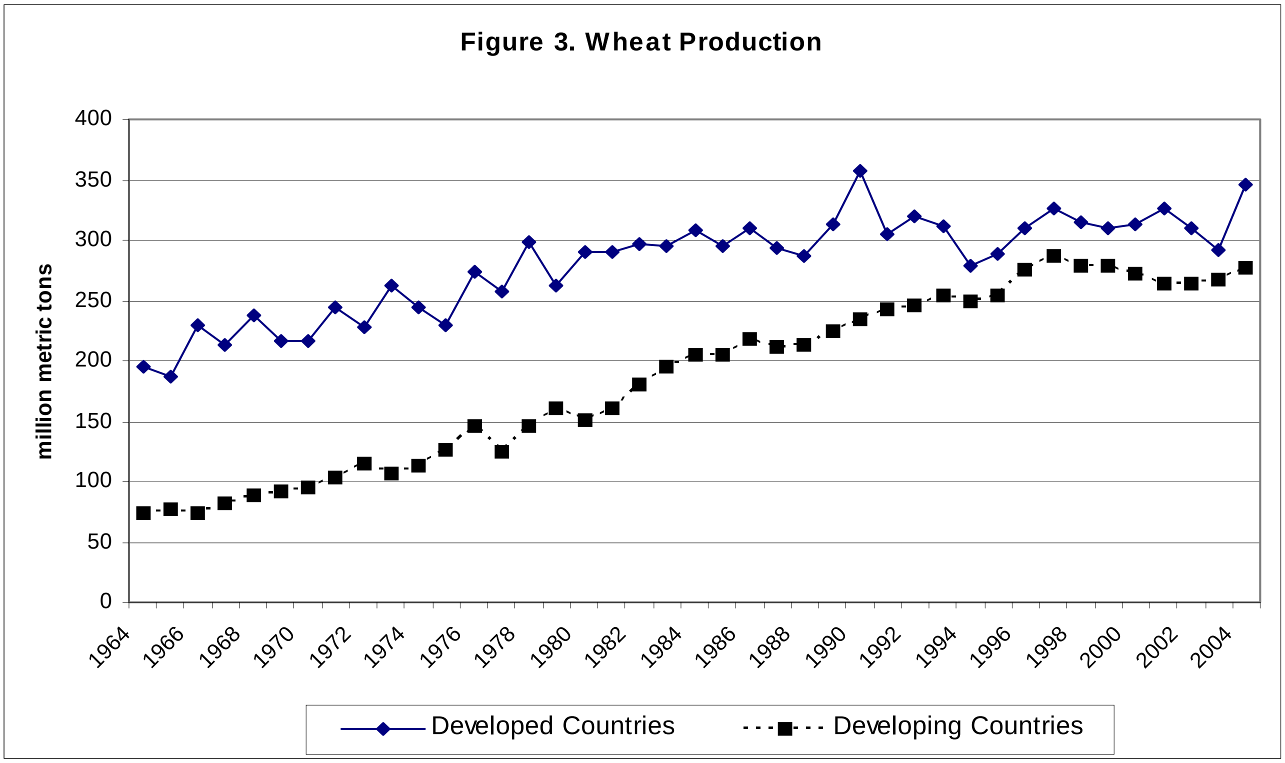
Many of the countries experiencing the largest production growth have also had the largest population growth, resulting in a greater need for food. Figure 2 shows the per capita agriculture production index. Even after accounting for population increases, the greatest percentage growth in production has been in developing countries. China and South America have shown the greatest growth in per capita production. Not all developing countries, however, have experienced significant production growth. Per capita production has actually declined in Africa, the Caribbean, and Oceania developing countries.

Figure 2. Per Capita Agriculture Production Index



Source: FAOSTAT

Wheat production in developed countries increased from 195 million metric tons in 1964 to 346 million metric tons in 2004, while production in developing countries increased from 74 million metric tons to 278 million metric tons during that same period (Figure 3). Wheat production in both developed and developing countries has leveled off in recent years. All of the production increase in developed countries over the 40-year period is due to yield increases, as area harvested has actually declined, and most of the production increase in developing countries is also due to yield increases. In the late 1960s, yields averaged 23.1 bu/acre in developed countries, 15.5 bu/acre in developing countries, and 14.1 bu/acre in the least developed countries. From 2000-2004, yields averaged 41.4 bu/acre in developed countries, 40.0 bu/acre in developing countries, and 23.2 bu/acre in the least developed countries (Table 1).



Source: FAOSTAT

Table 1. Increases in Worldwide Crop Yields

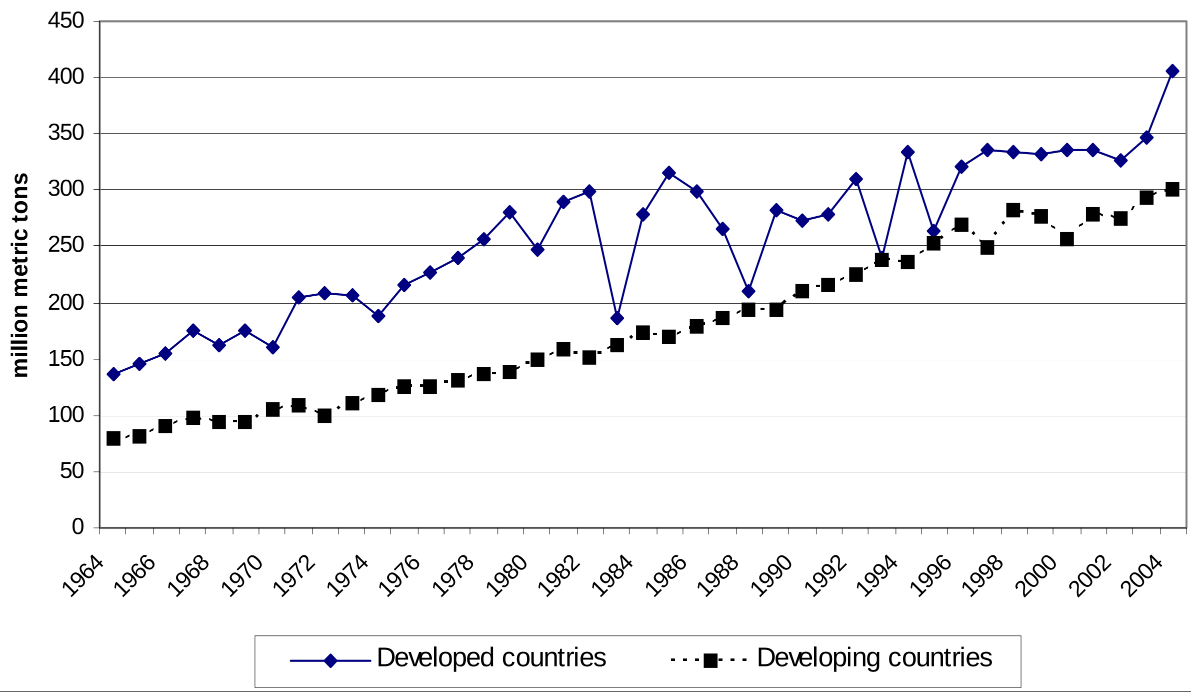
	1965-69	1980-89	2000-04
Wheat		(bushels per acre)	
Developed countries	23.1	33.7	41.4
Developing countries	15.5	29.7	40.0
Least-developed countries	14.1	19.7	23.2
Corn		(bushels per acre)	
Developed countries	61.0	87.8	116.4
Developing countries	21.4	34.3	48.0
Least-developed countries	15.3	17.8	20.8
Rice		(pounds per acre)	
Developed countries	4,562	4,920	5,788
Developing countries	1,818	2,735	3,422
Least-developed countries	1,401	1,913	2,728
Soybeans		(bushels per acre)	
Developed countries	24.8	29.7	37.7
Developing countries	13.4	22.4	30.9
Least-developed countries	11.6	12.2	14.9

Source: FAOSTAT

Wheat yields in developing countries have nearly reached those in developed countries, but yields in the least developed countries still lag behind. The increase in China has been remarkable, as yields have risen from 12.2 bu/acre in 1964 to 62.5 bu/acre in 2004. The largest increases in Chinese wheat yields occurred in the 1970s and early 1980s, likely due to expanded irrigation, new technology, increased use of chemical fertilizers, and breeding practices. Yield growth for Chinese wheat stalled in the mid- and late-1980s, possibly due to environmental stress (Huang and Rozelle 1995), but yields increased again in the late-1990s, and ongoing research could lead to even further gains in Chinese wheat yields (Ray 2005). Yields in the United States have increased from 25.8 bu/acre to 43.1 bu/acre over the 40-year period. Yields in Western Europe continue to be the highest.

Corn yields are still substantially higher in developed countries. From the late-1960s to the 2000-04 average, corn yields increased from 61.0 bu/acre to 116.4 bu/acre in developed countries, from 21.4 to 48.0 bu/acre in developing countries, and from 15.3 to 20.8 bu/acre in the least developed countries. Yields in the United States increased from 78.5 bu/acre to 141.5 bu/acre over the period. Corn production in both developed and developing countries has increased substantially over the last 40 years (Figure 4). The area harvested has remained relatively unchanged over the last few decades in developed countries, while it has increased in developing countries. Production continues to be greater in developed countries than in developing countries, despite more land area being harvested in developing countries.

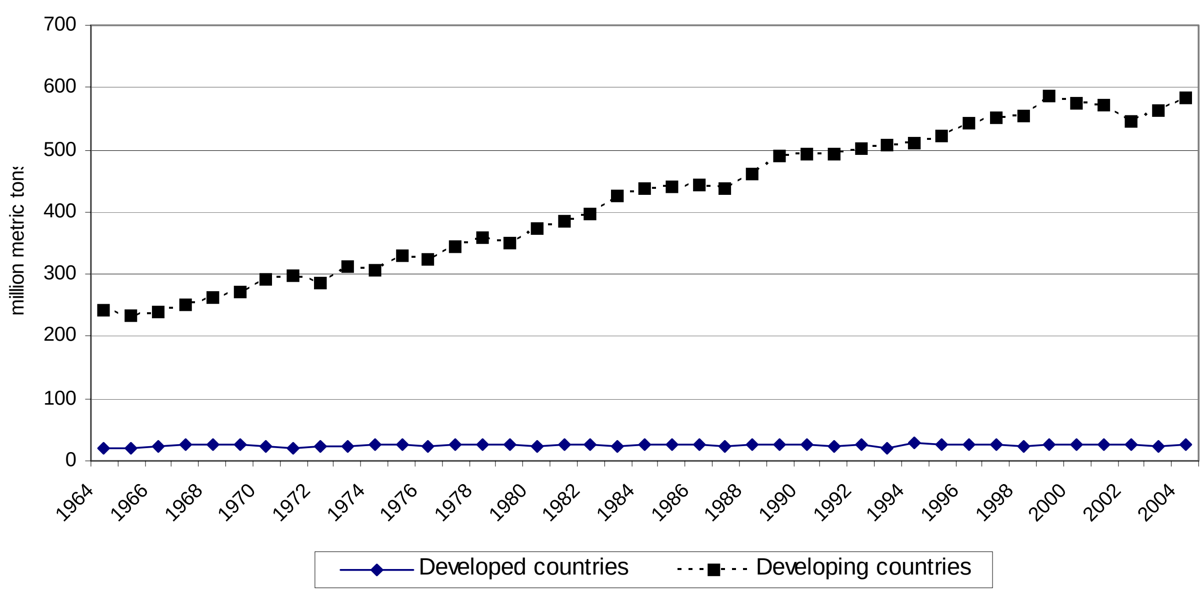
Figure 4. Corn Production



Source: FAOSTAT

Rice has experienced a more modest, but still significant, increase in yields. In the late-1960s, rice yields averaged 4,562 lbs/acre in developed countries, 1,818 lbs/acre in developing countries, and 1,401 lbs/acre in the least developed countries. By 2000-04, those yields increased to 5,788 lbs/acre in developed countries, 3,422 lbs/acre in developing countries, and 2,728 lbs/acre in the least developed countries. Rice yields have been increasing at a faster rate than the yields for other major crops in developing countries, but they are still significantly lower than those achieved in developed countries. The level of rice production in developing countries far surpasses the level of production in developed countries, despite the lower yields, because of much greater land area devoted to rice in these countries (Figure 5).

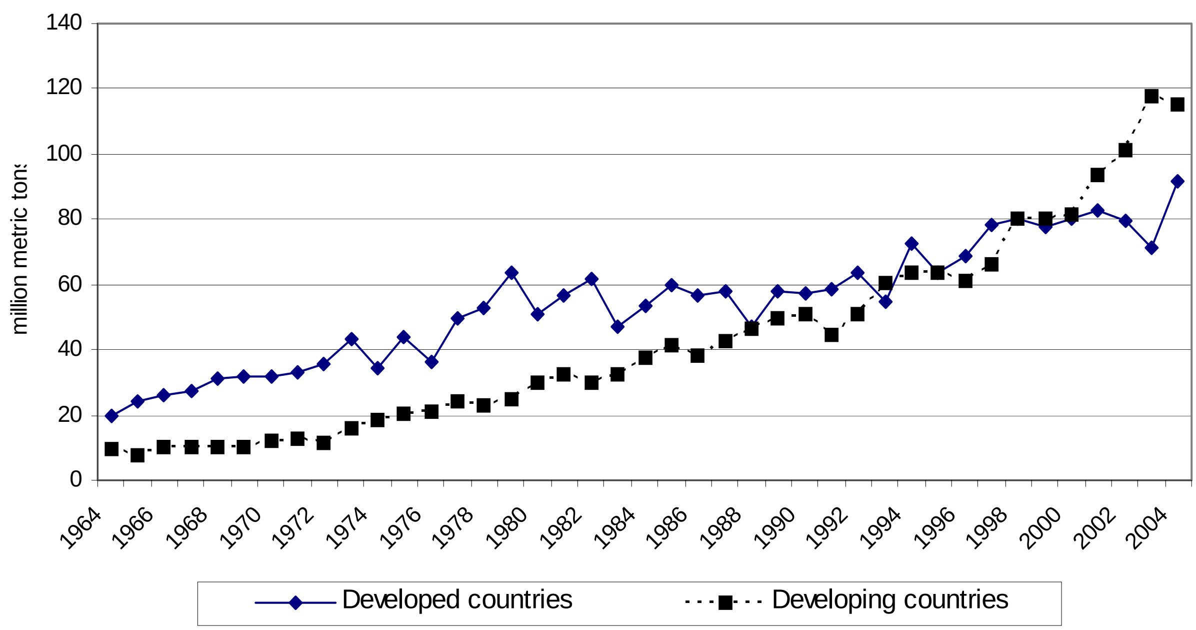
Figure 5. Rice Production



Source: FAOSTAT

Soybean yields tend to vary from year to year, but they have continued along a long-term upward trend. Yields in developed countries increased from 24.8 bu/acre in the late 1960s to a 2000-04 average of 37.7 bu/acre. During that same period, yields increased from 13.4 bu/acre to 30.9 bu/acre in developing countries and from 11.6 bu/acre to 14.9 bu/acre in the least developed countries. Yields have increased rather substantially in developing countries but have been stagnant in the least developed countries. Along with the increase in yields has been a large increase in soybean area harvested in developing countries. Since the late 1970s, soybean area harvested has not increased significantly in developed countries, but the area harvested in developing countries has more than tripled. Total production continues to increase in both developed and developing countries, but it has increased at a faster rate in developing countries (Figure 6). Brazil and Argentina have contributed significantly to the increase in soybean production.

Figure 6. Soybean Production



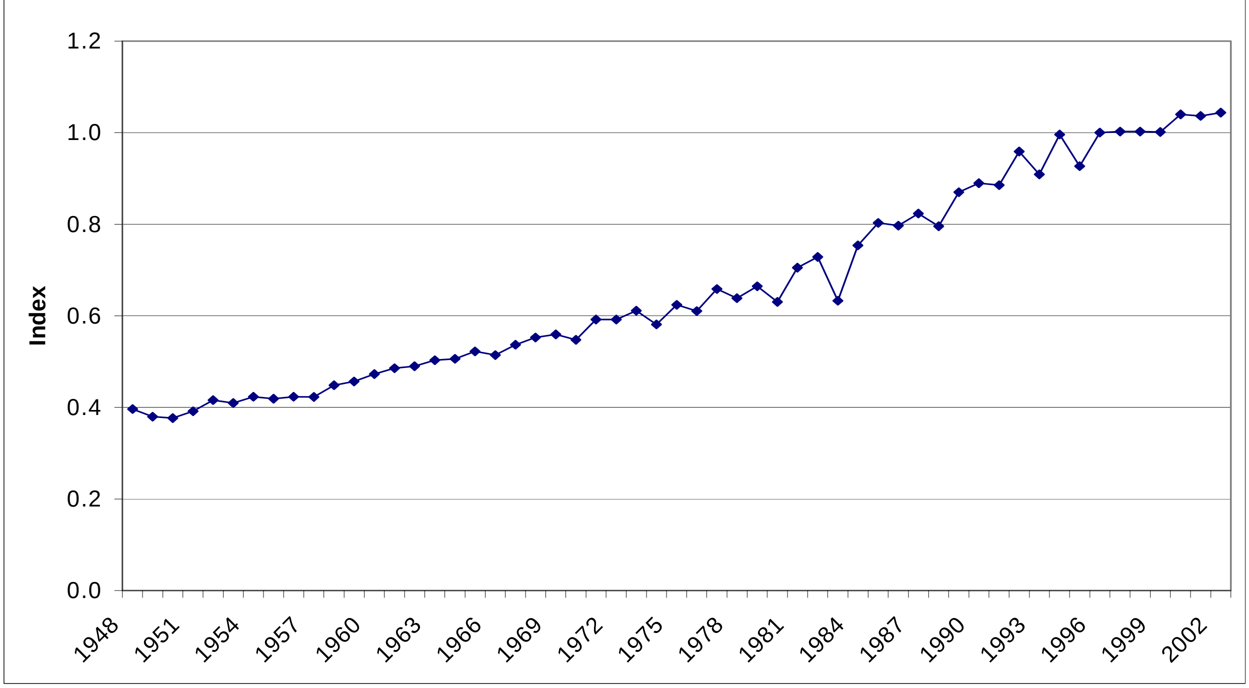
Source: FAOSTAT

Productivity Changes

Much of the increase in yields can be attributed to increased productivity. Estimates from the USDA's Economic Research Service (ERS) show that TFP for U.S. agriculture has been continually increasing since 1950 (Figure 7). ERS estimates show that TFP grew by an average of 1.8 percent per year from 1948 to 2002. The highest annual growth rates occurred in the late 1950s, the early 1970s, and the 1980s. The annual TFP growth rate from 1990 to 2002 slowed to 1.3 percent. Productivity growth accounts for the increased U.S. agricultural production. Since 1948, real expenditures on U.S. agricultural inputs, as estimated by ERS, have been relatively constant (labor expenditures have decreased significantly and chemical and energy expenditures have risen), while output has grown an average of 1.8 percent per year (Figure 8).

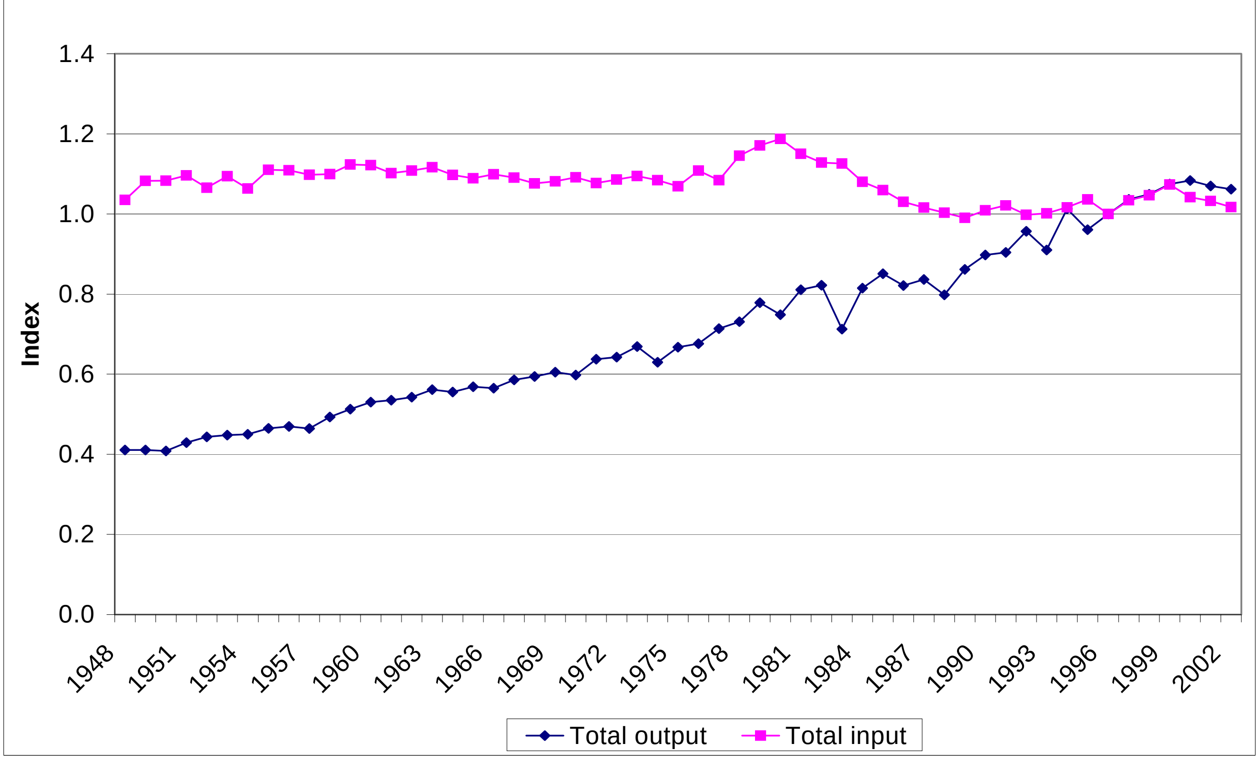
Studies have examined agricultural productivity in other countries across the world. The ERS found that from 1973 to 1993, the United States outperformed European countries in total output, but this was due to differences in the levels of land, labor, capital, and other inputs rather than productivity. They found that relative productivity for France was virtually the same as for the United States, but the Netherlands, Belgium, and Denmark had higher productivity. Shane, Roe, and Gopinath (1998) found that growth in agricultural productivity, particularly in the 1970s, has been higher in European countries than in the United States.

Figure 7. Total Factor Productivity for U.S. Agriculture



Source: ERS/USDA

Figure 8. Total Output and Input for U.S. Agriculture



Source: ERS/USDA

There have been contrasting studies on the rate of productivity growth in developing countries. Ruttan (2002) concluded that differences among developed and developing countries in output per hectare and per worker have widened. Fulginiti and Perrin (1998) noted that while studies of developed countries have found substantial productivity increases, studies of less developed countries have shown widespread productivity decline and technological regression. In their study, Fulginiti and Perrin examined productivity changes in a diverse group of 18 less developed countries from 1961 to 1985, and they found that agricultural productivity in these countries declined at an annual rate of 1-2 percent. They did find productivity gains in a few countries, but most countries showed losses.

Nin et al. (2003) argued that the previous findings of productivity declines in developing countries were due to the existence of biased technical change and the definition of technology used. Nin et al. used a new approach to estimate productivity, and they obtained different results. Out of a sample of 20 developing countries, Nin et al. found significant productivity growth in 16 countries during the 1961-1994 period, and only one country showed significant productivity regression.

Coelli and Rao (2003) also found widespread productivity increases in a study that examined data from 1980 to 2000. They found that over this period, Asia posted the highest annual TFP growth of 2.9 percent, followed by North America, Australia, Europe, Africa, and South America. Their study found no global or regional technological regression, but South America and Africa posted low growth rates of 0.6 percent and 1.3 percent, respectively, which is a concern considering that these two continents have experienced the largest population growth rates. Coelli and Rao found that China had the highest annual TFP growth rate of 6 percent, while the U.S. TFP growth rate was estimated at 2.6 percent during this period.

Both public and private research have been found to have positive effects on agricultural productivity, but the rate of return seems to be highest for publically funded research (Ahearn et al. 1998). Shane et al. (1998) found that three-fourths of U.S. productivity is accounted for by public investment in agricultural research and development and infrastructure. Ahearn et al. (1998) noted that agricultural research is needed not just to increase productivity but to keep it from falling. For example, yield gains for a particular plant variety tend to be lost over time because pests and diseases evolve that make the variety susceptible to attack.

Since there is little land available for expansion of agricultural production in the United States, growth in production will require increased yields. Growth of agriculture in the United States is dependent on productivity increases. Export competitiveness is also dependent on relative productivity growth against major competitors. Future productivity growth will be influenced by current and future research, especially public research.

Potential for Future Advancements in Production Agriculture

New developments that could lead to further productivity increases include improved technologies for nutrient, soil, water, and pest management; precision agriculture; and agricultural biotechnology (Caswell 2004). The emergence of biotechnology could especially have a significant impact on productivity worldwide. Currently, most of the genetically modified (GM) crops are produced in developed countries, with the United States producing the largest share. It is estimated that the United States accounted for 63 percent of GM crop production in 2003 (ERS website). GM crop production in the United States has been continually increasing since its introduction in the mid-1990s. In 2005, planted acreage of GM herbicide-tolerant crops expanded to 87 percent of U.S. soybeans and 61 percent of U.S. cotton (ERS website).

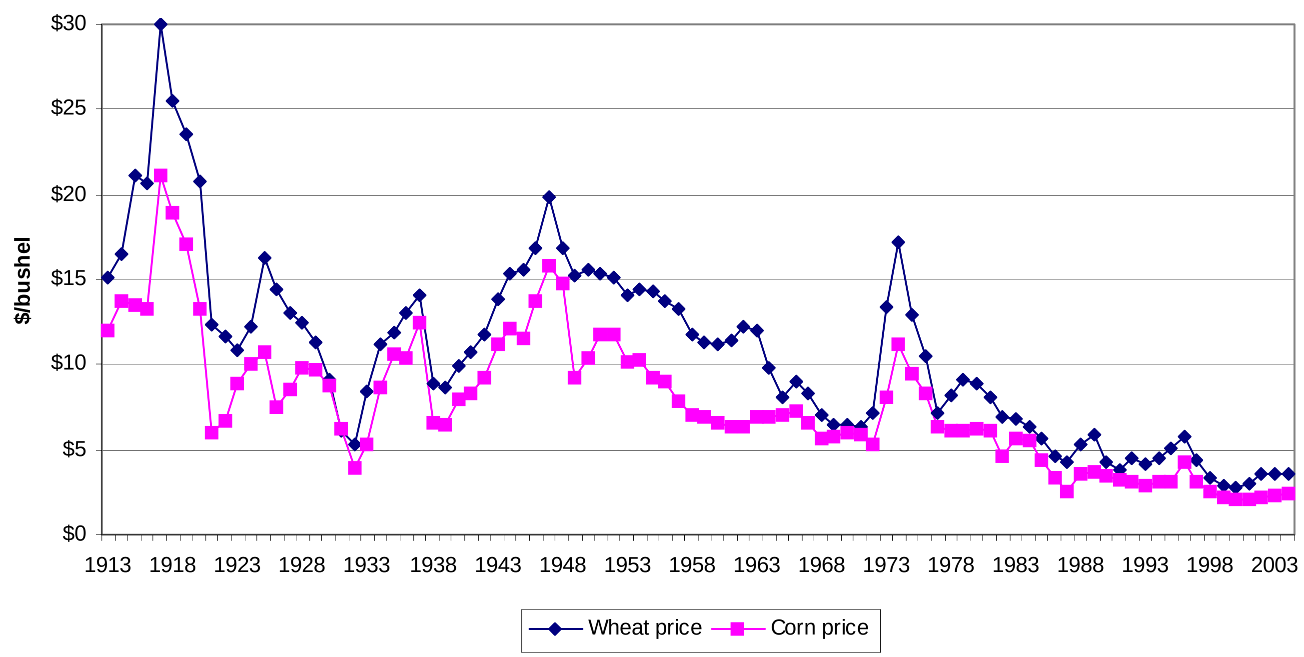
Farmers benefit from the use of GM crops through increased weed and insect control, which could lead to increased yields and decreased pesticide costs. Despite some consumer concern, the biotechnology trend is likely to continue as it leads to productivity gains for farmers. The introduction of GM wheat has been delayed, largely due to concern that consumers in export markets will not accept it, but it could eventually be adopted.

Who Benefits from Technological Advances?

Current biotech crops have been developed mainly to improve agricultural production. Future biotech crops could be introduced that have qualities such as increased nutritional content or other characteristics that would benefit consumers. Consumer response to the further adoption of biotech crops is uncertain, but it may become more favorable as these crops are developed with more obvious benefits for consumers. Developing countries could benefit the most from biotechnology through productivity gains and improved nutritional content of crops such as golden rice.

Also, while technological advances appear to initially benefit producers by leading to higher yields, lower costs, and increased productivity, consumers ultimately benefit from lower real food prices. This can be demonstrated by the decline in real commodity prices over time. For example, inflation-adjusted prices of wheat and corn were nearly three times higher in the 1970s than they are today, and they have followed a long-term downward trend over the last century (Figure 9). The lower commodity prices that result from agricultural productivity growth contribute to lower costs for the food processing industry, improving its competitiveness. Some of the decline in real commodity prices and processed food prices are passed on to the consumer. According to ERS data, food expenditures by U.S. consumers as a share of disposable personal income has dropped steadily from 24.2 percent in 1930 to 10.1 percent in 2003. Shane et al. (1998) found that, due to a decline in prices, the social rates of return to publically funded agricultural research and development are relatively high.

Figure 9. U.S. Real Wheat and Corn Prices



Note: Prices adjusted for inflation using the Consumer Price Index, base year=2004.
Source: National Agricultural Statistics Service/USDA

Effects of Demand Changes on Production

As incomes continue to grow in developed countries, consumer demand may increase for high-quality and specialty products, which could have an effect on production systems. For example, vertical integration or coordination has become prevalent in some agricultural sectors in the United States, such as in the pork and poultry industries. In these industries, the ties between input suppliers, producers, commodity buyers, food processors, and food distributors have become much closer. These food production systems may be able to produce a higher level of uniformity and quality which consumers prefer. Saxowsky and Duncan (1998) define industrialization as a trend in which firms adopt strategies to differentiate their product from those of other firms. This trend, which has led to increased contractual arrangements and vertical integration, may continue as producers seek to meet the demands of consumers. As consumer incomes rise in developed countries, price becomes less important, and producers and agribusinesses will have to respond to changes in consumer non-price preferences such as nutrition, safety, and convenience (Saxowsky and Duncan 1998).

New Uses for Agricultural Products

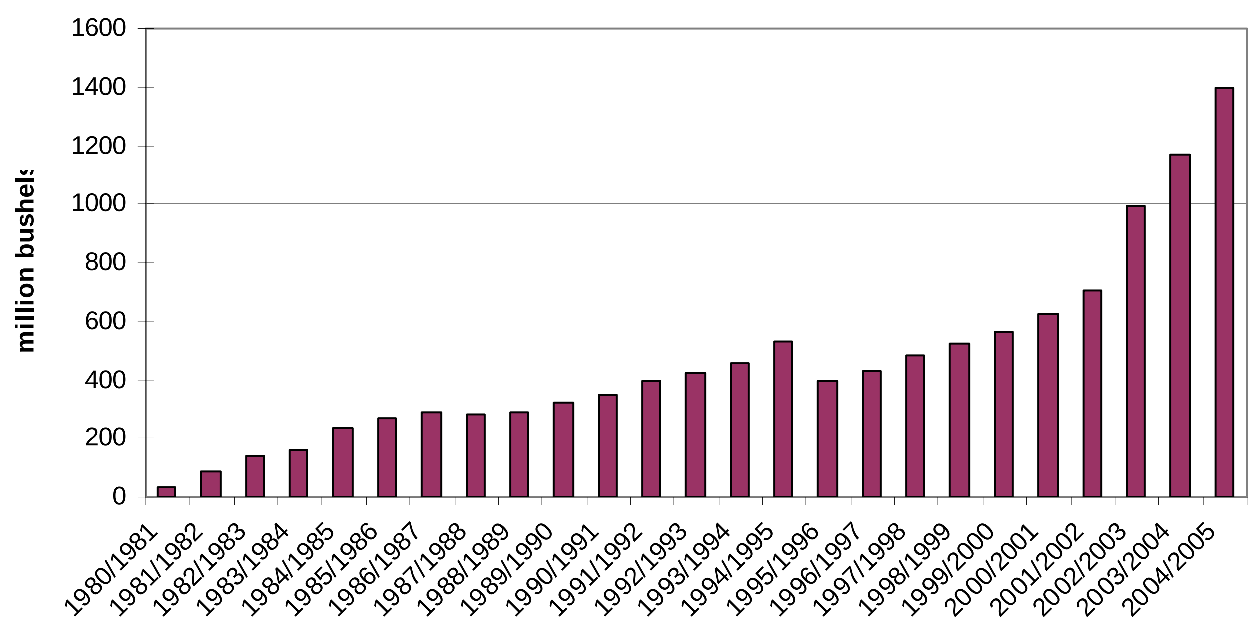
Research has also led to the development of many non-food uses for agricultural products, increasing the demand for and value of agricultural commodities. There has been a growing demand in recent years for the industrial use of agricultural products. The wide variety of industrial products that can be produced from agricultural commodities include biofuels such as ethanol and biodiesel, and numerous bio-based products such as adhesives, plastics, soaps and detergents, cosmetics, lubricants, inks, paints and coatings, and more (see, for example, Singh et al. 2003 and Lesney 2004).

The use of corn for the production of high fructose corn syrup (HFCS) grew rapidly in the 1980s and 1990s, but U.S. HFCS production has now peaked and stabilized, consuming 500-550 million bushels of corn per year, or about 5 percent of U.S. corn supply. The greatest increase in the use of corn recently has been for ethanol. Lesney (2004) writes that "with the growing demand for petroleum substitutes, and a burgeoning world population, many futurists believe the competition for agricultural production between the chemical feedstock industry and human consumption will be severe" (p. 26). The increasing use of biofuels, especially ethanol, has become an especially popular trend.

Biofuels

Biofuel is any fuel produced from plant material, vegetation, or agricultural waste. Ethanol produced from corn is the most common biofuel in the United States. Other biofuels include biodiesel, methanol, and methane. Most biodiesel in the United States is produced from soybeans, while canola is used to produce biodiesel in Europe. U.S. production of ethanol increased from 175 million gallons in 1980 to 3.9 billion gallons in 2005, and the amount of corn used for ethanol increased from 35 million bushels to 1.4 billion bushels, or from 0.5 percent to 12 percent of U.S. corn supply, during that period (Figure 10). Biodiesel production increased from 0.5 million gallons in 1999 to over 30 million gallons in 2004 (Schnepf 2005). New ethanol and biodiesel plants are continually being built. This trend, which is likely to continue for the near future, has been largely driven by government policy to promote domestically-produced renewable energy.

Figure 10. U.S. Corn Use for Ethanol



Source: National Agricultural Statistics Service/USDA

Federal subsidies help ethanol to overcome its higher cost relative to gasoline. The primary federal incentive is a production tax credit of $0.51 per gallon of pure ethanol (Schnepf 2005). Several states also have their own policies to promote the production and consumption of biofuels. Minnesota, for example, requires that 10 percent of gasoline purchased in the state consists of ethanol, and recent legislation would require this to increase to 20 percent by 2013.

Recent state bans of methyl tertiary butyl ether (MTBE) also provide incentive for increased ethanol use. MTBE is an oxygenate, which helps burn fuel more cleanly, reducing emissions. However, the gasoline additive has been found to pollute ground water. A minimum oxygenate level is required in some areas where pollution is high. MTBE has accounted for most oxygenate use, but since it was found to pollute ground water, a number of states have banned it. Ethanol is an oxygenate that has the potential to replace MTBE.

Support from the federal and state governments for biofuel production and consumption, especially ethanol, continues to grow. The 2005 energy bill passed by the U.S. Congress would require 7.5 billion gallons of ethanol or biodiesel to be consumed per year by 2012, which would nearly double the amount produced in 2005. The support for domestically-produced renewable energy is based on environmental concerns and a desire to lessen dependence on foreign oil, and it is also supported as a program to help U.S. farmers add value to their crops.

Assuming a yield of 2.8 gallons per bushel (Bothast 2005), an increase of 3.5 billion gallons of ethanol would consume 1.25 billion bushels of corn. This would be a significant increase in demand for corn. In recent years, the United States has produced about 9 billion to 12 billion bushels of corn per year and has exported about 1.5 billion to 2 billion bushels. Projected increases in ethanol production could result in 25 percent or more of the corn crop being used for ethanol.

Taylor et al. (2006) estimated that a mandated ethanol production level of 7 billion gallons per year by 2012 would increase corn prices by $0.08 in 2008, $0.10 in 2012, and $0.14 in 2014 above price levels that would have been achieved in those years without the mandate, and that increasing ethanol production to 14 billion gallons per year would increase price by $0.56 in 2012 and $0.68 in 2014. Other studies have similarly shown that ethanol production increases corn prices (Otto and Gallagher 2001, Ferris and Joshi 2004, Food and Agricultural Policy Research Institute 2005, McNew and Griffith 2005).

While the increase in demand for corn would have a positive effect on corn prices, other sectors of agriculture could also be affected. Costs for livestock producers would increase as the price of corn rises. Ferris and Joshi (2004) estimated a reduction in livestock production because of higher feed costs. Byproducts from ethanol production can be used as feed, which could provide some benefit to livestock producers. Under the dry-grind process, each bushel of corn produces about 18 pounds of dried distillers grains plus solubles (DDGS), which are a good source of protein and energy for cattle (Lardy 2003). DDGS could substitute for soybean meal, and an increased supply of DDGS would likely depress soybean meal prices, but the high corn prices could prevent soybean meal prices from declining. The byproducts from the wet-mill process are corn gluten meal and feed and corn oil. Ferris and Joshi (2004) estimated that prices of vegetable oils, including soybean oil, could decrease slightly because of increased corn oil production.

The outlook for the ethanol industry over the next decade may look bright, but the long-term outlook is more difficult to project. The existence of the industry depends largely on support from the government, and long-term public policy is difficult to predict. With recent increases in gasoline prices, on the other hand, the ethanol industry may be a viable industry even without government support. Sustained high gasoline prices would encourage increased expansion of alternative fuel production. It is possible that, as technologies develop, corn-based ethanol could eventually give way to new forms of renewable energy that offer greater advantages. Schnepf (2005) concludes that corn’s long-run potential as an ethanol feedstock is somewhat limited. The supply of corn limits its ability to have a very meaningful impact as a substitute for petroleum. Twelve percent of the total U.S. corn supply was used to produce just 1.6 percent of U.S. gasoline consumption in 2004. Doubling ethanol production would consume a large share of the U.S. corn crop, but it would still not have a very significant impact on petroleum consumption.

There are several other agricultural products that can be used as a feedstock for ethanol, and they may offer better long-term supply potential (Schnepf 2005). The cellulose from biomass can be used to produce ethanol. Switchgrass, in particular, has significant potential as an ethanol feedstock, and other potential feedstocks include corn stover, wheat straw, and fast-growing trees. The technology to produce cellulosic ethanol from these products is still rudimentary and expensive, but future technologies could make cellulosic ethanol less expensive than corn-based ethanol (Schnepf 2005). These feedstocks have an advantage over corn in that they can be grown less expensively on marginal land, and they also yield a higher net energy balance (U.S. Department of Energy 2005, McLaughlin and Walsh 1998). (The net energy balance refers to the amount of energy the fuel provides per unit of energy consumed to produce the fuel.) De La Torre Ugarte et al. (2003) found that large-scale production of switchgrass devoted for use as bioenergy would have a significant positive impact on U.S. agriculture in terms of prices and farm income.

Most biodiesel is produced from soybeans or canola, but it can be produced from any oil crop, from animal fats, or from waste vegetable oil. Studies have even examined the possibility of producing biodiesel from a type of algae that is high in oil content (Briggs 2004). Biodiesel also been shown to have a significantly higher net energy balance than corn-based ethanol (National Renewable Energy Laboratory 1998).

NEW MOVEMENTS IN DEVELOPING COUNTRIES

Brazil and Argentina as the Future Bread Basket of the World

Brazil and Argentina have become increasingly competitive in the world market as production in these two countries has grown dramatically in recent years. The largest increases have been in soybeans. The potential exists for substantial production increases to continue, especially in Brazil. Prior to 1970, there was very little soybean production in Brazil and Argentina.

Production increased gradually throughout the 1970s and 1980s. The increases accelerated significantly in the late 1990s, as production more than doubled within a short period (Table 2). From 1995/96 to 2004/05, soybean production increased from 24 million metric tons to 53 million metric tons in Brazil and from 12 million metric tons to 39 million metric tons in Argentina. Much of the increase in soybean production in these two countries was due to an increase in the area of land brought into production. From 1995/96 to 2004/05, the soybean area harvested increased from 10.9 million hectares to 22.8 million hectares in Brazil and from 6.0 million hectares to 14.4 million hectares in Argentina. U.S. soybean area equaled 29.9 million hectares in 2004. Yields have also been increasing in Brazil and Argentina and are similar to those in the United States.

Soybean production in the United States has also been increasing after stagnating in the 1980s, but the United States is no longer the dominant producer and exporter. The combined production in Brazil and Argentina now exceeds U.S. production, and although U.S. exports have been increasing, the United States has lost considerable market share to the two South American countries. In fact, projections for 2005/06 show the United States and Brazil having similar export levels for soybeans (USDA 2006b).

Production of other crops has also increased in Brazil. Brazil is the largest sugar producing country in the world, and its production has been increasing continually over the last decade, from 12.5 million metric tons in 1994/95 to 28.2 million metric tons in 2004/05. Cotton production in the country increased from 520 thousand metric tons in 1998/99 to 1.4 million metric tons in 2004/05.

Table 2. Soybean Area Harvested, Production, and Exports: Brazil, Argentina, and the United States

	1970/71	1980/81	1990/91	1995/96	2000/01	2004/05
Brazil						
Area Harvested (1000 HA)	1,716	8,501	9,750	10,950	13,934	22,917
Production (1000 MT)	2,077	15,007	15,750	24,150	39,500	53,000
Soybean Exports (1000 MT)	NA	NA	2,478	3,458	15,469	20,136
Soybean Meal Exports (1000 MT)	NA	NA	8,201	11,941	10,679	14,242
Soybean Oil Exports (1000 MT)	NA	NA	685	1,600	1,530	2,414
Argentina						
Area Harvested (1000 HA)	36	1,880	4,750	5,980	10,400	14,400
Production (1000 MT)	59	3,770	11,500	12,430	27,800	39,000
Soybean Exports (1000 MT)	NA	NA	4,468	2,087	7,415	9,513
Soybean Meal Exports (1000 MT)	NA	NA	5,556	8,223	13,600	19,880
Soybean Oil Exports (1000 MT)	NA	NA	1,100	1,556	3,211	4,720
United States						
Area Harvested (1000 HA)	17,098	27,443	22,870	24,906	29,303	29,930
Production (1000 MT)	30,675	48,921	52,416	59,174	75,055	85,013
Soybean Exports (1000 MT)	11,806	19,712	15,161	23,108	27,103	30,011
Soybean Meal Exports (1000 MT)	4,136	6,154	5,023	5,446	6,988	6,305
Soybean Oil Exports (1000 MT)	790	740	366	450	636	600

Source: PS&D Database, FAS/USDA

Argentina is a major exporter of wheat and corn, but production has been rather stable. Corn production has increased slightly due to yield increases, and wheat production has been mostly constant since the mid-to-late 1990s. Brazil also produces corn, but it is consumed domestically. Argentina and Brazil are both major producers of beef. Brazil is the second-largest beef producing country after the United States, and Argentina is the fourth-largest. Brazil has the largest cattle herd in the world, and it recently exceeded Australia as the largest beef exporter. The increased availability of soybean meal has led to rapid growth in the poultry sector (Holger et al. 2004). Brazil was the third-largest poultry meat producing country in 2004, after the United States and China, and the fifth-largest producer of pork.

The rate of soybean expansion slowed in 2003 and 2004 in Brazil and Argentina, but Brazil still has the potential for much greater increases due to available land that could be brought into production. Brazil has vast tracts of uncultivated savannah land in the Center-West region of the country known as the Cerrado. Most of the recent expansion in production has been in this region, but there is significant room for more growth. The United States currently has more land devoted to crops (an estimated 174 million hectares) than Brazil (42 million hectares) (Foreign Agricultural Service (FAS) 2003). The FAS (2003), however, notes that Brazil has the potential to have far more land devoted to cultivated agricultural crops than the United States because of its more favorable climate, its relatively flat topography, and its enormous supply of arable soils that are conducive to mechanized farming.

The Cerrado Savanna consists of 207 million hectares, and only 47 million hectares, much of which consists of animal pasture, have been brought into agricultural production (Vado et al. 2004). Vado et al. (2004) note that Brazil's Agricultural Research Organization, EMPRAMPA, estimates that an additional 89 million hectares in the Cerrado could be developed for large-scale, mechanized agriculture in the near future. Government policy in Brazil requires that when new land is brought into cultivation, a certain amount of land needs to be set aside and kept as natural vegetation (Holger et al. 2004). Holger et al. (2004) estimate that, given current government regulations, an additional 60 million hectares of land in the Center-West could be converted to cultivated production, and 50 million hectares of that area are good, flat tracts of land on the plateaus.

Much of the agricultural land in Brazil is currently pasture, but a large number of the country's vast pastures could be converted to cultivated crops. The FAS (2003) estimates that Brazil could increase its cultivated land area by 170 million hectares or more. They estimate that 70-90 million hectares of Brazil's existing pasture acreage, which is about 40-50 percent of the nation's total pasture, as well as 65 million hectares of virgin savannah land and up to 10 million hectares of degraded pasture or deforested land in the Amazonian states, could be converted to crops.

The recent expansion of land in the Center-West was made possible due to technological breakthroughs. Soybean production began in the temperate southern region of Brazil and was limited to that region because the tropical soils further north were not well-suited for production. Expansion to the north became possible after scientists learned how to use the tropical soils and when soybean varieties were developed that were suitable to the Brazilian climate (Schuh 2004). These technological developments significantly improved the production capacity in Brazil, and they demonstrate the importance of agricultural research.

These vast tracts of quality, uncultivated land are favorable for continued expansion in Brazil, creating increased competition for the United States in the world market. Since China is the biggest and fastest-growing market for soybeans, the ability of the United States to compete with Brazil and Argentina in this country is critically important. In recent years, the United States held close to a 50 percent market share in China for soybeans, and Brazil held about a quarter of the market. As China's soybean imports doubled in 2002/03, to 21 million metric tons, U.S. soybean exports to the country reached a high of 7.7 million tons, which is more than a quarter of all U.S. soybean exports. However, U.S. market share in China dropped to 38 percent, while Brazil's market share increased to 36 percent. For the first time, Brazil's market share in China was nearly equal to that of the United States (FAS, October 2003). The USDA (2006a) has projected that Brazil's soybean exports will continue to increase at a significant pace over the next decade while U.S. exports will level off, making Brazil the leading exporter of soybeans and soybean products.

Researchers have conducted analyses about the production costs of oilseeds in Argentina and Brazil (Dohlman et al. 2001, McVey et al. 1999, Arburn et al. 1991). Dohlman et al. (2001) compared marketing, transportation, and farm-level production costs in the late 1990s and found that Brazil and Argentina maintained a competitive advantage over the United States in production costs, mainly due to higher land costs in the United States. They found that lower transportation and marketing costs in the United States partially offset the production cost disadvantage, but that Brazil and Argentina have been reducing these costs in recent years. Huerta and Martin (2002) also noted that land values are lower in Brazil and Argentina, but that these two countries face other issues that reduce their competitive advantage, including economic instability and inadequate transportation infrastructure. Flaskerud (2003) estimated that the costs of production for the 2003 harvest were lower in Mato Grosso, Brazil, than in North Dakota and Iowa, even when freight costs were considered. He calculated total cost per bushel, including freight cost to Rotterdam, as $4.57 in Mato Grosso, $5.76 in North Dakota, and $7.21 in Iowa. Costs are higher in North Dakota than Mato Grosso primarily because of higher land and machinery expenses and lower yields. Production cost is highest in Iowa because the state has the highest land costs.

Macroeconomic variables also affect competitiveness. Schuh (2004) concluded that Brazil has a monetary policy which makes it more competitive. He explained that Brazil and Argentina have a large external debt, and in order to service this debt, they have allowed their currencies to decline. The International Monetary Fund (IMF) has encouraged poor countries in debt to devalue their currencies in order to increase export sales. Their weak currencies give exporters from Brazil and Argentina an advantage over U.S. exporters. Andino et al. (2005) found that the depreciation of Brazilian and Argentine currencies has negatively affected U.S. soybean exports.

There are some factors limiting expansion in Brazil. The most notable limiting factor is the transportation system. The current transportation infrastructure in the Center-West increases the costs of production and hinders significant further expansion. However, Brazil has been increasing its investment in its transportation infrastructure (Caixeta-Filho 2003). Reis and Weinhold (2004) note that the Brazilian government has allocated $3 billion for approximately 7,500 km of new Amazonian highways through 2007.

Other factors could also limit expansion in Brazil. The outbreak of soybean rust in recent years has resulted in reduced yields. Due to the spread of this disease, the use of chemicals has increased, and production costs have risen (Yorinori et al. 2005). Another new expense in Brazil is the royalties paid to use the newly legalized biotech soybean seed. Holger et al. (2004) noted that three additional factors could slow expansion of cultivated land in the Center-West: the agrarian reform movement, calls to expand the Indian reserve, and environmental pressures to preserve the natural forest.

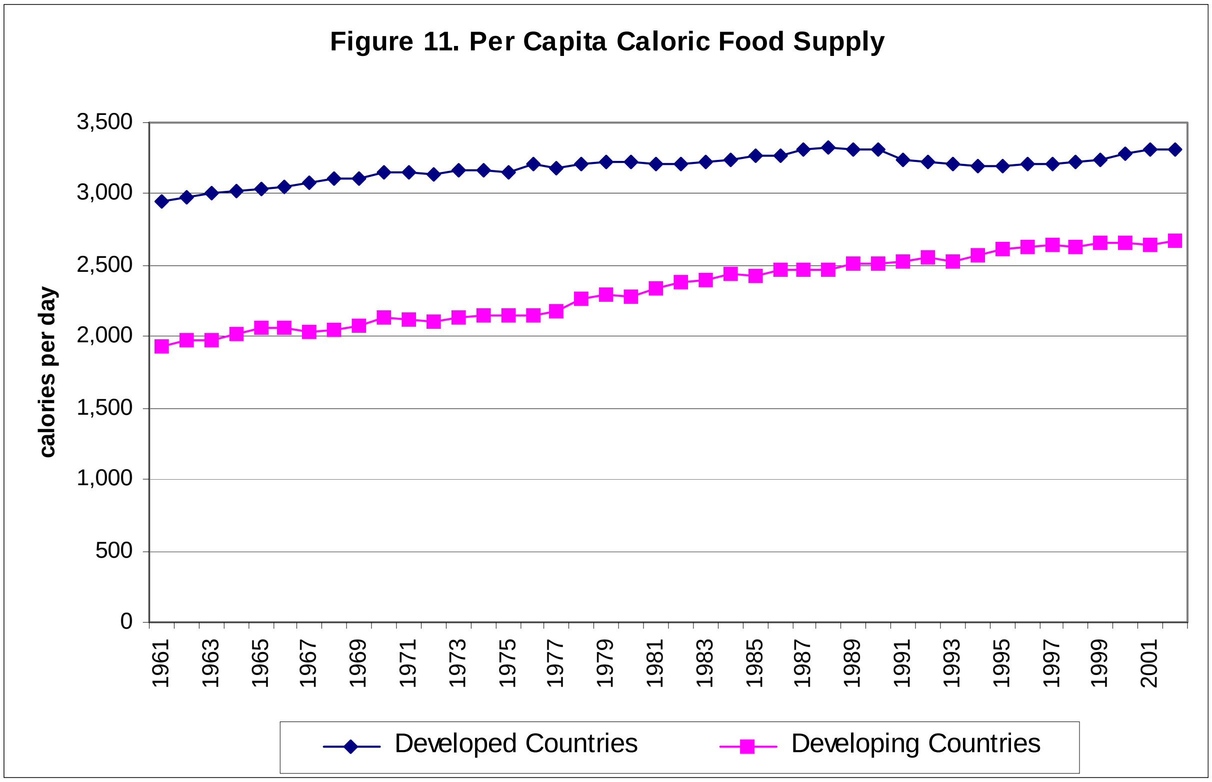
China and other Developing Countries and the Worldwide Demand for Food

As China, India, and other developing countries continue to grow, their demand for food will increase, and rising incomes in these countries could result in shifts in demand. This could further result in significant changes in world trade flows. Data on food consumption over the last few decades show the changes in demand in developed and developing countries for different agricultural products.

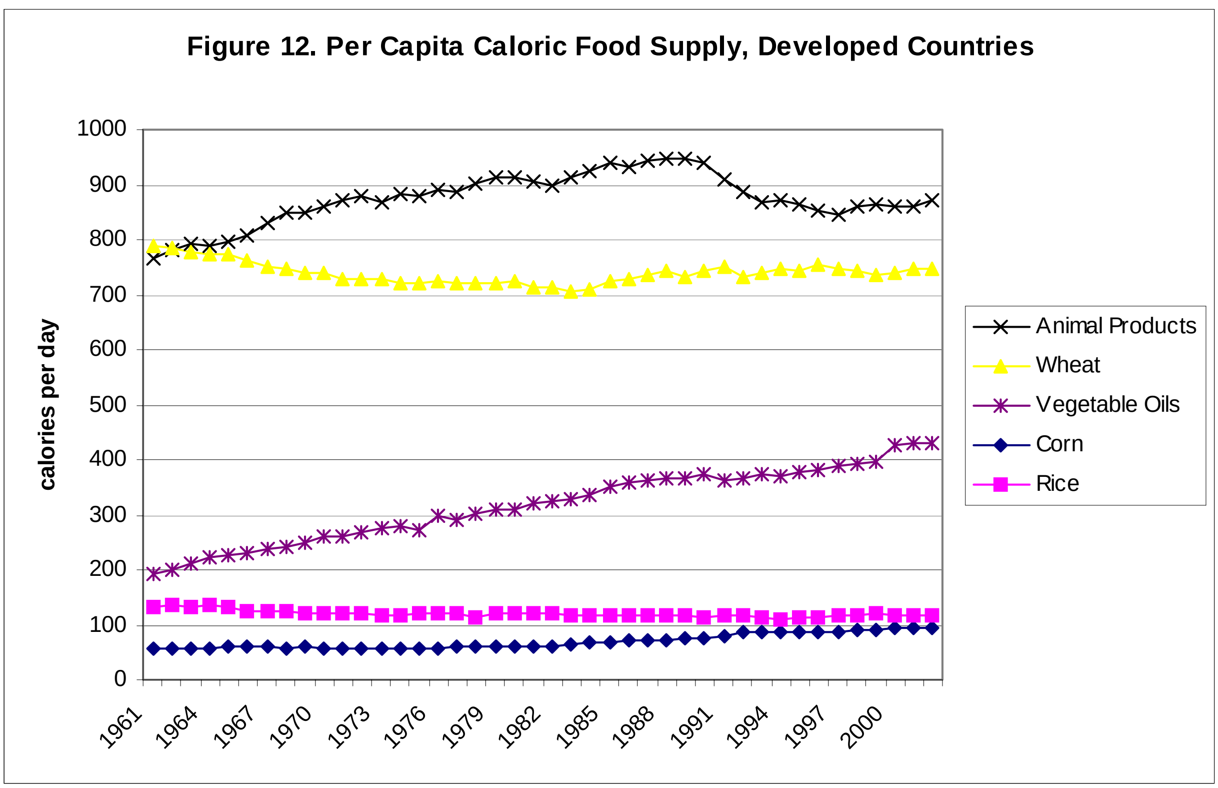
Data are available from FAOSTAT (2005) showing per capita food supplies in calories available for human consumption. These numbers do not exactly represent consumption, but they can be taken as an approximation of average per capita consumption. Per capita caloric consumption has increased in both developed and developing countries over the past few decades. The rate of per capita consumption growth has been faster in developing countries, but a gap still remains between developed and developing countries (Figure 11). Per capita consumption may have peaked in developed countries, but it will likely continue to rise in developing countries as income in these countries increases.

Changing tastes and income levels affect the types of food consumed. In developed countries, per capita consumption of vegetable oils has increased considerably (Figure 12). Animal products and wheat constitute the largest shares of the diet in developed countries. However, per capita wheat consumption in these countries has leveled off. Consumption of animal products had been increasing until the late 1980s; while consumption declined in the early 1990s, it has since rebounded slightly. Per capita rice consumption in developed countries has been rather constant, while corn consumption has increased slightly.

Rice accounts for the largest share of the diet in developing countries, followed by wheat (Figure 13). Per capita consumption of both rice and wheat had been increasing in these countries until the mid-to-late 1980s. Since then, it has been relatively constant. Consumption of animal products is now growing the fastest in developing countries, and vegetable oil consumption is also increasing significantly. If per capita income in developing countries continues to grow, per capita consumption of animal products and vegetable oils are likely to continue increasing, while per capita consumption of rice and wheat may have peaked.

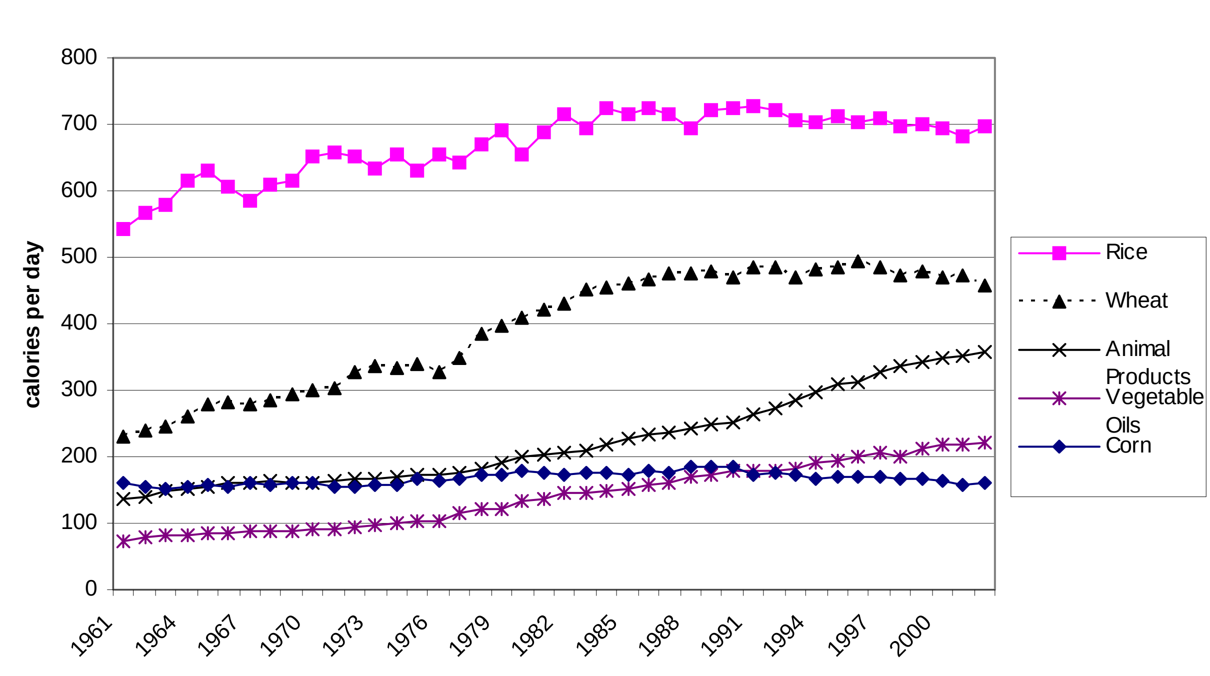


Source: FAOSTAT



Source: FAOSTAT

Figure 13. Per Capita Caloric Food Supply, Developing Countries

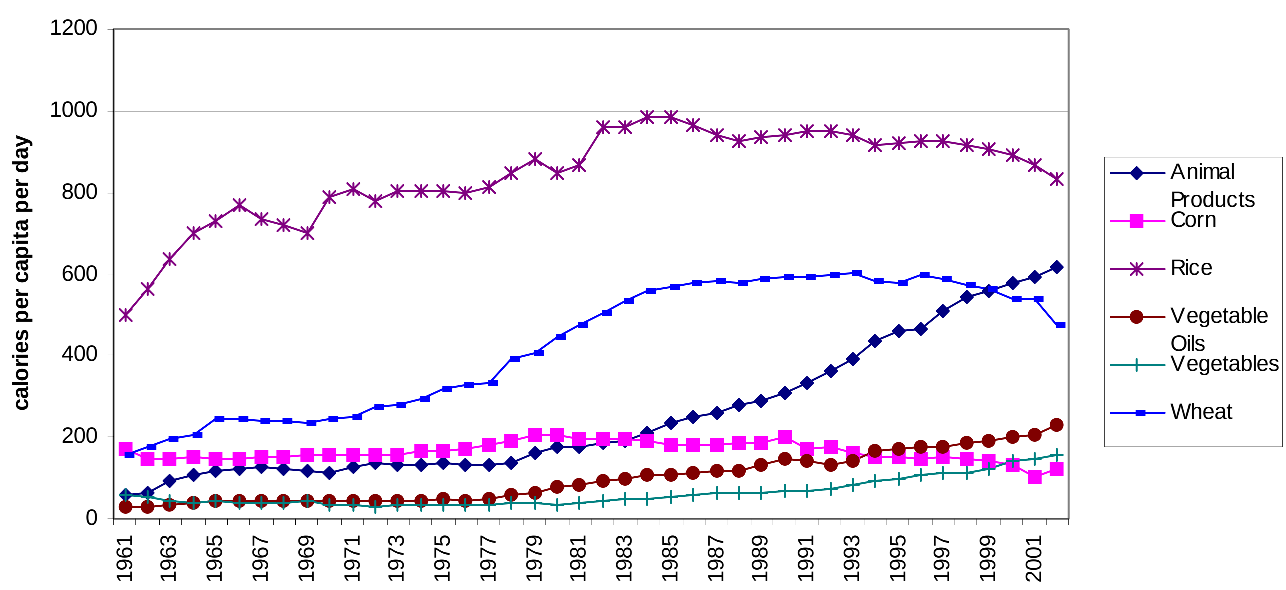


Source: FAOSTAT

Increased demand for meat in developing countries could also have a significant influence on the demand for animal feeds such as corn and soybean meal. Chinese imports of soybeans, which are used to produce soybean meal and soybean oil, have increased dramatically in recent years. Much of this increase can be attributed to growing demand for meat and vegetable oil (Figure 14). China is a major consumer of vegetable oils, and while the country is currently self-sufficient in most major food items, they are reliant on imports for this product (Gale 2005). The growing demand for soybean meal in China is driven by production of hogs, poultry, and fish (Gale 2005).

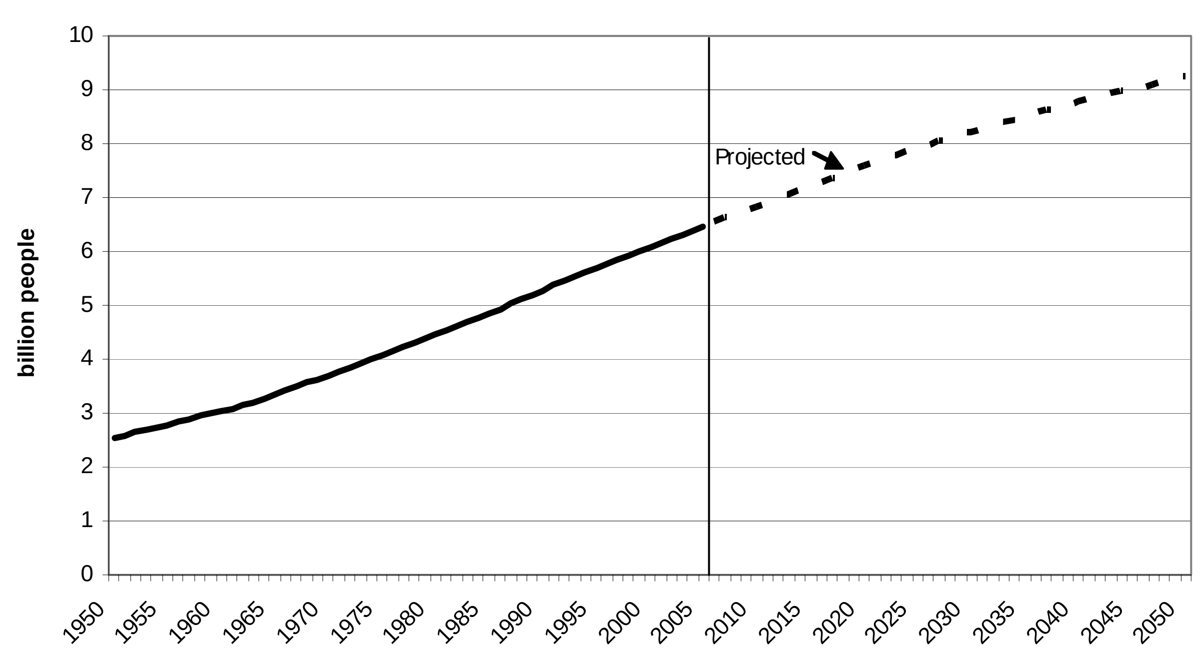
Total worldwide food consumption has increased not just because of per capita increases but also because of a growing global population. World population is expected to continue to grow, although at a decreased rate, from 6.5 billion in 2005 to 9.2 billion in 2050 (Figure 15). Increased production will be required to meet the growing demand for food. Population growth rates vary significantly by country. According to U.S. Census Bureau (2005) projections, many of the countries with the largest expected percentage increases in population are in Africa or the Middle East. Developing countries, in general, are expected to have higher annual population growth rates, as has been the case in recent years. Many European countries, as well as Japan, Russia, and South Africa, are expected to lose population. In the United States, population is expected to continue to grow at a rate of about 0.7 to 0.9 percent per year. By 2050, the largest actual increases in population (rather than percentage increases) are expected to be in India, Nigeria, Bangladesh, Pakistan, the United States, Congo, and China (in this order). China's population is expected to peak around 2030 and then decline slightly. India is projected to surpass China as the world's most populous country in 2034.

Figure 14. Chinese Food Supply



Source: FAOSTAT

Figure 15. World Population



Source: U.S. Census Bureau, International Data Base

SUMMARY

Worldwide agricultural production is likely to become more competitive as a result of increased trade liberalization through the WTO and regional and bilateral free trade agreements. As a result, product specialization within countries will increase based on resource endowments. Production will increase in the countries that are the most efficient. Countries can become more competitive through agricultural research and development. Research in Brazil, for example, has helped that country become increasingly competitive in the world market.

Over the last several decades, total agricultural production has been increasing significantly across the world. The increase in total production has been largely due to higher yields. Increased yields and productivity are the result of technological advancements that began with the Green Revolution and continue today with biotechnology and other improvements in production. Agricultural research has led to higher yielding crop varieties, better livestock breeding practices, more effective fertilizers and pesticides, and better farm management practices. Future productivity increases will be influenced by public spending on agricultural research. Most countries, with the exception of Brazil, cannot significantly expand agricultural production land area, so future production increases will largely need to come from continually improving yields.

While technological advances initially appear to benefit producers by leading to higher yields, lower costs, and increased productivity, consumers ultimately benefit by lower real food prices. This can be demonstrated by the decline in real commodity prices over time. Consumers could also benefit from biotechnology through increased product quality, and there could be some environmental benefits from these technological advancements as well.

Increased production will be needed to satisfy increasing demand for agricultural products. This demand is based on a growing worldwide population (resulting in increased food consumption), rising incomes, and changing consumer tastes causing shifts in demand, and on the increasing use of agricultural products for industrial purposes.

In developed countries, per capita consumption of vegetable oils has increased considerably in recent years. As incomes continue to grow in developed countries, consumer demand may increase for high quality and specialty products, which could have an effect on production systems. Consumption of animal products is now growing the fastest in developing countries, and vegetable oil consumption is also increasing significantly, while per capita consumption of rice and wheat may have peaked. These trends should continue if per capita income in these countries continues to grow. Increased demand for meat in developing countries could also have a significant influence on the demand for animal feeds such as corn and soybean meal.

An increasing percentage of agricultural goods are being used for industrial purposes. The wide variety of industrial products that can be produced from agricultural commodities includes biofuels such as ethanol and biodiesel, and numerous bio-based products. The increasing use of biofuels, especially ethanol, has become an especially popular trend. This is leading to an increase in demand for corn, which should positively affect corn price. The use of other crops for biofuels could also increase significantly in the long run, such as soybeans for biodiesel or switchgrass or other products for ethanol.

In the past, agricultural production has been more than able to keep pace with increases in demand, and as a result, real prices have declined over time. In the future, however, prices of some commodities could increase if demand grows at a faster rate than production.

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Appendix 1. FAOSTAT Classification of Countries

Developed Countries	Developed Countries (cont.)	Developing Countries
Albania	San Marino	Afghanistan
Andorra	Serbia and Montenegro	Algeria
Armenia	Slovakia	American Samoa
Australia	Slovenia	Angola
Austria	South Africa	Anguilla
Azerbaijan, Republic of	Spain	Antarctica others
Belarus	Svalbard and Jan Mayen	Antigua and Barbuda
Belgium	Sweden	Argentina
Bosnia and Herzegovina	Switzerland	Aruba
Bulgaria	Tajikistan	Bahamas
Canada	Turkmenistan	Bahrain
Channel Islands	Ukraine	Bangladesh
Croatia	United Kingdom	Barbados
Czech Republic	United States	Belize
Czechoslovakia	USSR	Benin
Denmark	Uzbekistan	Bermuda
Estonia	Yugoslavia SFR	Bhutan
Faeroe Islands		Bolivia
Finland		Botswana
France		Bouvet Island
Georgia		Brazil
Germany		British Indian Ocean Ter
Gibraltar		British Virgin Islands
Greece		Brunei Darussalam
Holy See		Burkina Faso
Hungary		Burundi
Iceland		Cambodia
Ireland		Cameroon
Isle of Man		Canton and Enderbury Is
Israel		Cape Verde
Italy		Cayman Islands
Japan		Central African Republic
Kazakhstan		Chad
Kyrgyzstan		Chile
Latvia		China
Liechtenstein		Christmas Island
Lithuania		Cocos (Keeling) Islands
Luxembourg		Colombia
Macedonia		Comoros
Malta		Congo, Dem Republic of
Moldova, Republic of		Congo, Republic of
Monaco		Cook Islands
Netherlands		Costa Rica
New Zealand		Côte d'Ivoire
Norway		Cuba
Poland		Cyprus
Portugal		Djibouti
Romania		Dominica
Russian Federation		Dominican Republic

Developing Countries (cont.)	Developing Countries (cont.)	Developing Countries (cont.)
Ecuador	Martinique	Sierra Leone
Egypt	Mauritania	Singapore
El Salvador	Mauritius	Solomon Islands
Equatorial Guinea	Mayotte	Somalia
Eritrea	Mexico	SouthGeorgia/Sandwich Is
Ethiopia	Micronesia,Fed States of	Sri Lanka
Falkland Is (Malvinas)	Midway Islands	Sudan
Fiji Islands	Mongolia	Suriname
French Guiana	Montserrat	Swaziland
French Polynesia	Morocco	Syrian Arab Republic
French Southern Terr	Mozambique	Tanzania, United Rep of
Gabon	Myanmar	Thailand
Gambia	Namibia	Timor-Leste
Gaza Strip (Palestine)	Nauru	Togo
Ghana	Nepal	Tokelau
Greenland	Netherlands Antilles	Tonga
Grenada	Neutral Zone	Trinidad and Tobago
Guadeloupe	New Caledonia	Tunisia
Guam	Nicaragua	Turkey
Guatemala	Niger	Turks and Caicos Is
Guinea	Nigeria	Tuvalu
Guinea-Bissau	Niue	Uganda
Guyana	Norfolk Island	United Arab Emirates
Haiti	Northern Mariana Is	Uruguay
Heard and McDonald Is	Oman	US Minor Outlying Is
Honduras	Pacific Islands Trust Tr	US Virgin Islands
India	Pakistan	Vanuatu
Indonesia	Palau	Venezuela,Bolivar Rep of
Iran, Islamic Rep of	Palestine, Occupied Tr.	Viet Nam
Iraq	Panama	Wake Island
Jamaica	Papua New Guinea	Wallis and Futuna Is
Johnston Island	Paraguay	West Bank
Jordan	Peru	Western Sahara
Kenya	Philippines	Yemen
Kiribati	Pitcairn Islands	Zambia
Korea, Dem People's Rep	Puerto Rico	Zimbabwe
Korea, Republic of	Qatar	
Kuwait	Réunion	
Laos	Rwanda	
Lebanon	Saint Helena	
Lesotho	Saint Kitts and Nevis	
Liberia	Saint Lucia	
Libya	Saint Pierre & Miquelon	
Madagascar	Saint Vincent/Grenadines	
Malawi	Samoa	
Malaysia	Sao Tome and Principe	
Maldives	Saudi Arabia	
Mali	Senegal	
Marshall Islands	Seychelles	

Least Developed Countries
Afghanistan
Angola
Bangladesh
Benin
Bhutan
Burkina Faso
Burundi
Cambodia
Cape Verde
Central African Republic
Chad
Comoros
Congo, Dem Republic of
Djibouti
Equatorial Guinea
Eritrea
Ethiopia
Gambia
Guinea
Guinea-Bissau
Haiti
Kiribati
Laos
Lesotho
Liberia
Madagascar
Malawi
Maldives
Mali
Mauritania
Mozambique
Myanmar
Nepal
Niger
Rwanda
Samoa
Sao Tome and Principe
Senegal
Sierra Leone
Solomon Islands
Somalia
Sudan
Tanzania, United Rep of
Timor-Leste
Togo
Tuvalu
Uganda
Vanuatu
Yemen
Zambia