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Productivity Growth in U.S. Agriculture

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Gains in productivity have been a driving force for growth in U.S. agriculture. The effects of these changes over the second half of the 20th century were dramatic: between 1950 and 2000, the average amount of milk produced per cow increased from 5,314 pounds to 18,201 pounds per year, the average yield of corn rose from 39 bushels to 153 bushels per acre, and each farmer in 2000 produced on average 12 times as much farm output per hour worked as a farmer did in 1950. The development of new technology was a primary factor in these improvements.

ERS has extended its productivity accounts to cover the period from 1948 through 2004. This statistical series can be used to identify the separate roles of changes in input use and changes in technology, as measured by total factor productivity growth, in driving growth in U.S. agricultural output. While measured agricultural productivity growth can fluctuate sharply from year to year, largely in response to weather developments, the longrun trends have remained quite high, particularly when compared with the private nonfarm economy. After 1980, capital, land, labor, chemical, and energy inputs to agriculture fell, even as agricultural output continued to grow, and increased productivity hence drove all of the output growth. In turn, high rates of productivity growth limited price increases—between 1948 and 2004, agricultural commodity prices rose at less than half the rate of economywide prices.

This bulletin is one of two new products by ERS on productivity in U.S. agriculture. The other bulletin reviews the return to public investment in agricultural research and its impact on productivity in the farm sector (see ERS Economic Brief, *Economic Returns to Public Agricultural Research*).

Improvements in Productivity Drive Agricultural Growth

There are many reasons for the impressive improvements in U.S. agriculture in the late 20th century. The greater use of agricultural inputs, such as more fertilizer and more machinery per acre of land, was one reason. But yield was also increased through the development of new technology, which made inputs more effective or allowed inputs to be combined in new and better ways.

ERS has developed the total factor productivity (TFP) statistical series, which isolates the effect of changes in technology and related factors from those effects that result from changes in inputs on the growth of agricultural output (see box on p.6, "Explaining Total Factor Productivity"). In the long run, growth in TFP is the primary source of new wealth creation. The trend in TFP, therefore, is an important indicator of the longrun performance of the agricultural sector in the United States.

Figure 1 shows changes in total output (an aggregation of crop and livestock commodities and related services), total inputs (an aggregation of land, labor, capital, and intermediate inputs like fertilizer, feed and seed), and TFP from 1948 to 2004. These changes are measured as indices with 1948 set equal to 100. For output, the index value reached 266 in 2004, meaning that total agricultural production in 2004 was 2.66 times higher than in 1948. Over the same period, aggregate input use in agriculture actually decreased slightly.

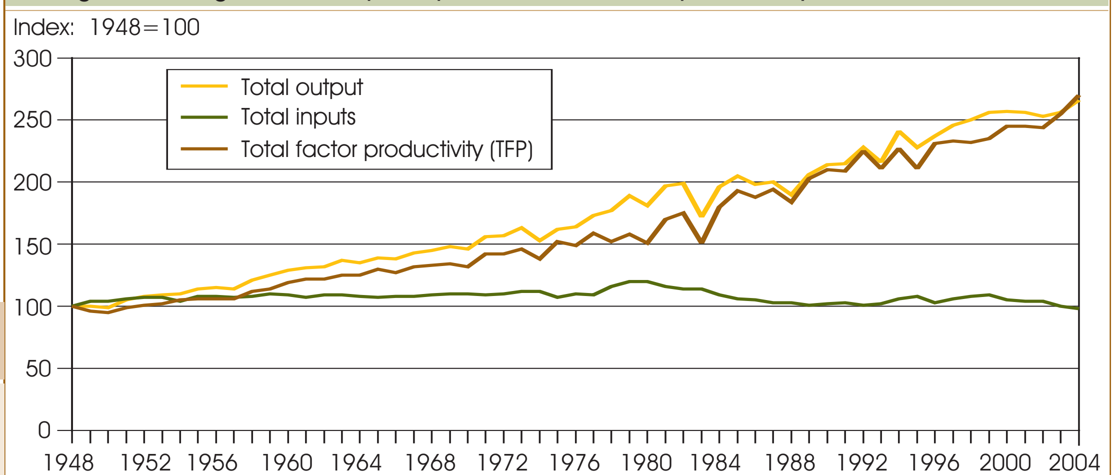
Although the use of some inputs like fertilizer and machinery increased, these increases were more than offset by reductions in cropland and especially the amount of labor employed in agriculture. Overall, the amount of crop and animal output produced per unit of (aggregate) input, which is measured by TFP, increased 2.70 times. As figure 1 shows, agricultural productivity growth was strong in each decade, allowing output to grow with little or no increase in inputs throughout the 1948-2004 period. In agriculture, TFP growth saved natural resources (especially land) and freed labor for employment in other sectors.

Agricultural Productivity Growth Lowers the Cost of Farm Commodities

Productivity growth in agriculture allows farm commodities to be grown and harvested more cheaply. This benefits not only farmers but also food and textile manufacturers and consumers. Most of these cost reductions are passed on to the nonfarm economy as lower commodity prices. Figure 2 shows the trend in the average price paid for all agricultural inputs and the average price received for agricultural outputs, as well as the trend in the general producer price level of the U.S. economy. From 1948 to 2004, the prices paid for farm inputs rose at roughly the same rate as general producer price inflation. Prices of farm commodities, on the

Figure 1

Changes in U.S. agricultural output, inputs, and total factor productivity[1] since 1948



[1] Total factor productivity measures total output per total inputs, or the overall efficiency of agricultural production.
Source: Economic Research Service.

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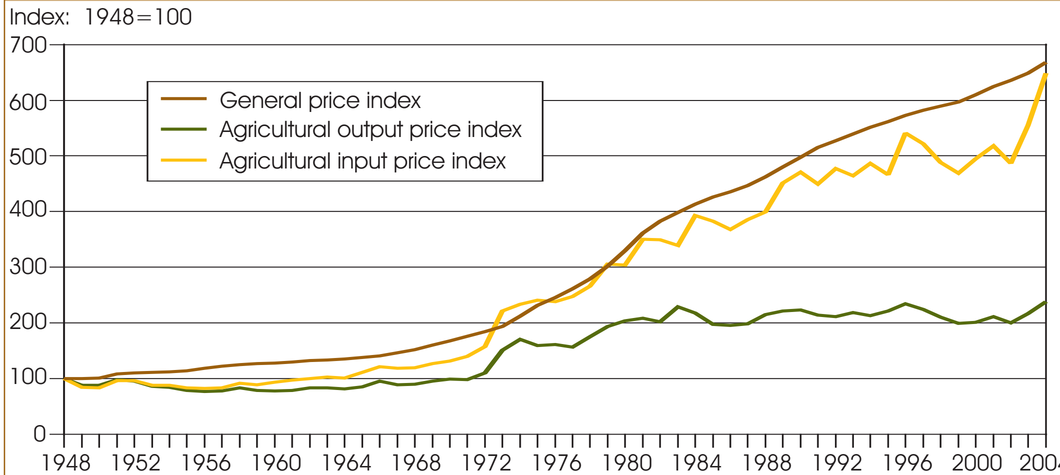
Figure 2

Trends in agricultural input and output prices



Source: Economic Research Service (agricultural output and input price indexes) and *Economic Report of the President* (general price index for the U.S. gross national product).

other hand, doubled in the 1970s but hardly changed at all afterward. The growing divergence between prices paid for farm inputs and prices received for farm products in figure 2 closely parallels the growth in TFP that was shown in figure 1. Productivity growth allowed more output to be produced from the same amount of inputs, reducing the average cost of production. The gains in productivity largely benefited agricultural processors and consumers in the form of lower real prices. Productivity growth in agriculture is a key reason why, on average, the American consumer spends a small and declining share of family income on food.

Year-to-Year Fluctuations in Agricultural Productivity Are Large

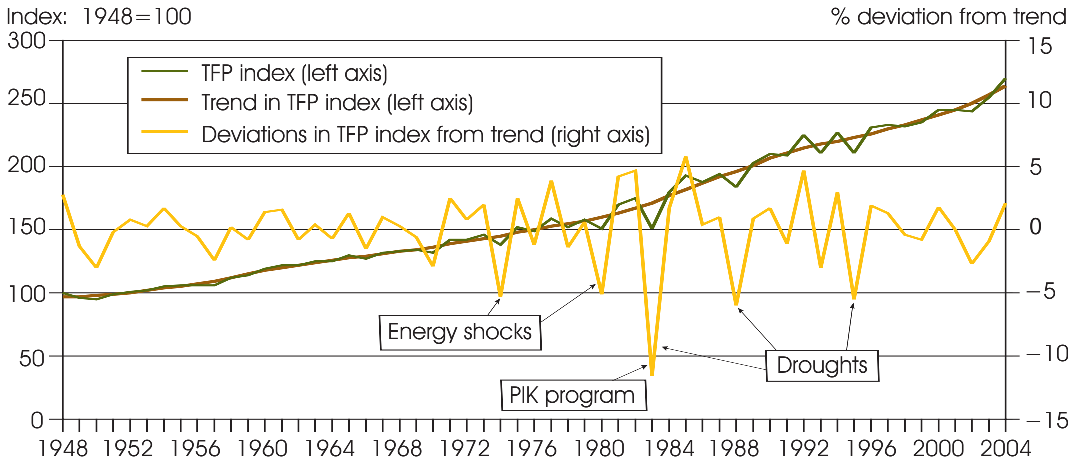
Although the longrun trend shows that agricultural productivity growth has been sustained over the past several decades, there is significant year-to-year fluctuation in productivity due to weather, policy interventions, general economic conditions, and other factors. Since the inputs employed in agriculture are relatively fixed over the short run, annual fluctuations in output are highly correlated with annual fluctuations in measured productivity.

Figure 3 fits a longrun trend line to TFP using a Hodrick-Prescott filter (measured along the left axis) and shows the annual deviations in TFP growth from trend (measured on the right axis) from 1948 to 2004. The deviations in TFP are shown as percent deviation from the trend line and scaled up to better illustrate the year-to-year fluctuations. Over the entire period, TFP grew at an average rate of 1.8 percent per year. During the 1950s and 1960s, TFP growth was relatively stable and annual fluctuations in the growth rate were never more than 5 percent off trend. Beginning in the early 1970s and continuing to the mid-1990s, growth in agricultural output and TFP showed greater annual fluctuations from trend. This can be partly explained by a number of specific events, such as the global energy crises of 1974 and 1979, serious droughts in 1983, 1988 and 1995, and an agricultural policy intervention in 1983 where the Federal Government encouraged farmers (through the Payment-In-Kind, or PIK program) to reduce crop production in order to lower accumulated government-held commodity surpluses.

One lesson from the pattern of fluctuations observed in figure 3 is that it can be misleading to estimate a trend from just a few years of data. For example, for the 10-year period between 1993 and 2002, TFP grew by only 0.8 percent per year, less than half of the longrun trend of 1.8 percent per year. However, changing by only 1 year the period over which the average is calculated gives a very different picture: the average annual growth in TFP during 1992-2001 was 1.6 percent and during 1994-2003 was 1.9 percent, both close to the longrun trend.

Figure 3

Annual fluctuations in agricultural TFP[1]



[1] Total factor productivity measures total output per total inputs, or the overall efficiency of agricultural production.
Source: Economic Research Service.

Another lesson from the pattern of fluctuations is the importance of weather for agricultural output and productivity measures. The impact of weather applies to both short-term fluctuations and long-term trends. Global climate change is likely to affect the longrun performance of the agricultural sector as well as pose a risk of greater frequency of extreme weather events that could increase instability in agricultural production.

To Increase Output, Agriculture Relies on Productivity Growth More Than Most U.S. Industries

Agriculture is more dependent on improvements in technology as a source of growth than the rest of the U.S. economy. Table 1 gives a breakdown of the sources of growth in the agricultural sector and all private industry from 1960 through 2004 (we used this time period because comparable data are available for those years). Overall growth in industrial production during this period was almost double that of agriculture, reflecting the shrinking share of the farm sector in the national economy. While growth in TFP accounted for 13 percent of the growth in all industrial output over this period, it accounted for 117 percent of the growth in agricultural output. The high rate of TFP growth in agriculture helped to free farm labor for employment in the rest of the economy. TFP growth also reduced the need for more nonlabor inputs such as land and capital to sustain growth in agricultural production. Improvements in agricultural TFP contributed significantly to the overall productivity growth of the U.S. economy. A recent study found that between 1960 and 2004, even though agriculture accounted for only 1.8 percent of industrial GDP, it accounted for 12.1 percent of all of the TFP growth in private industry over this period (Jorgenson et al., 2006).

Sources of Agricultural Productivity Growth Have Shifted Over Time

Although the longrun rate of growth in agricultural output was fairly steady from 1948 through 2004, the nature of that growth has shifted in important ways. In the 1950s, 1960s, and 1970s, labor was exiting agriculture very quickly (falling by almost 4 percent per year), and the increased use of nonlabor inputs, such as new machinery and improved chemicals, helped to substitute for the loss of farm labor. This substitution was reflected in rising amounts of cropland, machinery, and other inputs employed per farmworker. The rising cost of labor relative to other inputs encouraged farmers to adopt technologies and farming methods that saved on labor and used more nonlabor inputs instead. In more recent decades, however, there was a shift to new technologies that saved nonlabor inputs as well as labor, even as output continued to expand.

These changes can be shown by examining trends in agricultural output per hour worked (which is a more precise definition of labor productivity than output per worker) as well as changes in use of nonlabor inputs per hour worked. Although the shift occurred gradually, we chose 1980 as an approximate dividing mark to illustrate this long-term development. In table 2, we first decomposed growth in output into changes in output per hour worked and changes in total hours worked (output growth is simply the sum of these two components). Then, we further break down changes in labor productivity into the share of this growth that was due to rising amounts of nonlabor inputs employed per hour worked, to improvement in workers' skills (measured by levels of education and experience), and to total factor productivity. This is done for the whole period, and the periods 1948-1980 and 1981-2004.

Table 1—Sources of growth in U.S. agriculture sector and all industries, 1960-2004

	U.S. agriculture	All U.S. industries
	Percent	
Average annual growth in output	1.67	3.20
Share of output growth due to:		
Growth in nonlabor inputs	11.8	54.1
Growth in labor hours	-34.2	23.7
Growth in labor quality	5.6	8.8
Growth in TFP[1]	116.8	13.4
	100.0	100.0

[1]Total factor productivity is a statistical series developed by the Economic Research Service to isolate the effects of changes in technology and related factors from other changes in inputs on the growth of agricultural output.

Sources: Economic Research Service (agricultural statistics) and Jorgenson, et al., 2006 (statistics for all U.S. industries).

Over the whole period (1948 to 2004), agricultural labor declined by 3.2 percent per year but output per worker increased by 4.9 percent per year, enabling farm output to grow by an average annual rate of 1.7 percent (table 2). Increases in land, capital and other nonlabor inputs per hour worked accounted for 60 percent of the growth in labor productivity, while TFP growth accounted for 37 percent of the rise in labor productivity and improvements in labor quality the remainder during this period. Between 1948 and 1980, increases in nonlabor inputs per hour worked accounted for 74 percent of labor productivity growth while TFP accounted for 24 percent of this increase. However, since 1981, annual growth in TFP accelerated and was responsible for nearly two-thirds of the total increase in labor productivity during these years.

Table 2—Sources of labor productivity growth in agriculture

	1948-2004	1948-1980	1981-2004
		Percent	
Growth rate in agricultural output	1.7	1.9	1.6
Growth rate in labor hours worked	-3.2	-3.9	-2.1
Growth rate in labor productivity (output/hour)	4.9	5.8	3.7
Contribution to growth in labor productivity from:			
Increase in inputs per worker	3.0	4.3	1.2
Improvements in labor quality[1]	0.1	0.2	0.1
Growth in TFP[2]	1.8	1.4	2.4
	4.9	5.8	3.7
Share of growth in labor productivity due to:			
Increase in inputs per worker	60	74	33
Improvements in labor quality[1]	2	3	1
Growth in TFP[2]	37	24	66
	100	100	100

[1]Higher quality labor comes from having a larger share of better educated and more experienced workers in the farm labor force.

[2]Total factor productivity is a statistical series developed by the Economic Research Service to isolate the effects of changes in technology and related factors from other changes in inputs on the growth of agricultural input.

Source: Economic Research Service.

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Explaining Total Factor Productivity

When economists talk about "productivity," they may mean either output per unit of a particular input like labor, or output per unit of all inputs, which includes labor, capital, and all other inputs employed in production. The latter measure is known as total factor productivity. TFP is the output per unit of all inputs combined. It provides a more complete indicator of the economic efficiency of an industry.

Although growth in TFP is often interpreted as a measure of technological change, it is an imperfect measure. TFP is computed by subtracting the growth contributions of all inputs from the growth of output, so it reflects anything that causes output to grow faster than the combined growth of all inputs. Analysts have attributed growth in TFP to factors such as innovation (new technology), but TFP is also affected by economies of scale, measurement error, the educational attainment of the labor force, the regulatory environment, and managerial ability.

To compute agricultural TFP growth, analysts first estimate the rate of growth in agricultural output of each crop and animal commodity and derive a weighted growth rate for the output of the whole sector. Analysts then derive an estimate of the aggregate rate of change in all inputs employed in agriculture. They include:

- cropland
- machinery
- buildings
- inventories
- labor
- intermediate inputs" (including seed, feed, fuel, fertilizer and pesticides)

The inputs are adjusted for changes in quality (the amount of labor is adjusted to reflect rising educational attainment of the average farmworker, the amount of pesticides is adjusted to reflect the need for lower concentrations per acre for new chemicals, and so forth). Then the inputs are combined to produce an index of the aggregate rate of change in total inputs employed in agriculture. Growth in TFP is defined as the difference between the growth rate of total output and the growth rate of total inputs. For example, if agricultural output grew by 2.20 percent and total inputs grew by 1.05 percent between 1998 and 1999, then TFP grew by 1.15 percent (the difference between 2.20 percent and 1.05 percent) between those years.

The rate of change in nonlabor inputs per hour worked slowed considerably and accounted for only one-third of the growth in labor productivity.

What these figures suggest is that there has been a shift over time in the way agricultural productivity has grown. Instead of relying primarily on the development and adoption of new farming methods that substitute nonlabor inputs for farm labor, agricultural productivity growth is increasingly based on finding better ways to manage and save on a whole range of inputs. One way this transformation has occurred is by improvement in the quality of inputs such as machinery and chemicals. New kinds of farm chemicals and ways of applying them have in some cases led to reduced chemical loads per acre without sacrificing crop yield. In livestock production, larger scale and closer integration among farm producers, input suppliers, and processors have improved animal husbandry practices and saved on capital, labor, and feed. In recent years, applications of new biotechnology and information technology to agriculture have also been a source of productivity growth for the sector.

How Do Policies Affect Agricultural Productivity Growth?

Government policies affect the rate of agricultural productivity growth in both the shortrun and in the longrun. Specific policy interventions may cause measured productivity to rise or fall sharply from one year to the next (for example, the PIK Program coupled with drought in 1983; see figure 3). Shortrun fluctuations in productivity growth usually rebound quickly within 1 or 2 years. Policies that affect the longrun rate of productivity growth are more important for the longrun performance of the agricultural sector. These include macro-economic policies that encourage new investment and policies that encourage agricultural research and innovation. Both the public and private sectors invest heavily in research to develop new technology for the farm sector. (See the related ERS Economic Brief, *Economic Returns to Public Agricultural Research*, for analysis of the economic returns to public investments in agricultural research in the United States.)

This brief is drawn from . . .

Economic Research Service, Agricultural Research and Productivity briefing room, available at: www.ers.usda.gov/Briefing/AgResearch.

Economic Research Service, Agricultural Productivity in the United States data sets, available at:,www.ers.usda.gov/Data/AgProductivity.

Jorgenson, Dale W., Mun S. Ho, John Samuels, and Kevin J. Stiroh. October 2006. "The Industry Origins of the American Productivity Resurgence." Working Paper, Department of Economics, Harvard University, Cambridge, MA.

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