

U.S. Agricultural Growth and Productivity: An Economywide Perspective. By Mathew Shane, Terry Roe, and Munisamy Gopinath, Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 758.

Abstract

Growth of U.S. agriculture is dependent on increases in productivity, three-fourths of which is accounted for by public investment in agricultural research and development (R&D) and infrastructure, according to this research. Productivity growth in U.S. agriculture benefits consumers by putting downward pressure on real primary and processed food prices. Moreover, maintaining export growth in international markets relies on relative productivity growth against major competitors. Public investments in agricultural R&D have stagnated since the mid-1970's, raising questions about sustained productivity growth in U.S. agriculture.

Keywords: Agricultural growth, agricultural research and development, total factor productivity growth, public investments, international trade negotiations.

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Competitiveness Study: This paper is part of a series that focuses on issues related to U.S. agricultural competitiveness in global markets. The current list of background reports is included at the end of this paper under Project Outputs. The study was financed, in part, by a National Research Initiative Competitive Grant from the Cooperative State Research, Education and Extension Service, USDA.

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Summary

Productivity growth has been the dominant factor underlying U.S. agricultural growth since at least the 1950's. Without productivity growth, the agricultural sector would have declined both in absolute terms and relative to the rest of the economy. The fact that productivity growth has averaged more than double real price declines means that the sector can continue to produce and profit in spite of declining prices. Productivity growth was much more important for agriculture than for the overall economy, where more than 70 percent of growth was caused by additions of labor, capital, and material inputs. Because of the large number of producers and the dispersed nature of production, public investments have been a very important source of productivity growth for agriculture. We estimate that public agricultural R&D and infrastructure accounted for 75 percent of the growth in agricultural productivity between 1949 and 1991.

Productivity growth mostly benefits consumers by putting downward pressure on primary and processed food prices. The food processing sector is linked to primary production agriculture through the purchase of inputs. Consumers have benefited not only from the price declines of agricultural commodities, but also from the productivity growth of the food processing sector. The larger relative share of the consumer dollar going to processors and marketing is due to increasing consumer demand for more value-added from the food and fiber sector.

High relative productivity growth of primary agriculture is also a major factor in maintaining and fostering export growth and competitiveness of U.S. food and agricultural products in international markets. With the phasing down of commodity payments for agriculture under the 1996 Farm Act, public support for agricultural R&D and rural infrastructure becomes an increasingly important means to support agriculture in the future. However, although productivity growth remains high, public investments in R&D have slackened in the 1990's, raising questions about sustained productivity growth in the future.

U.S. Agricultural Growth and Productivity

An Economywide Perspective

Mathew Shane
Terry Roe
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Introduction

The purpose of this report is to investigate the sources of U.S. agricultural growth and their importance to the broader economy. As the U.S. economy has grown, the agricultural share of gross domestic product (GDP) has fallen from 4 percent in 1959 to 1.4 percent in 1996, a pattern common to most developed countries. The United States remains the world's largest agricultural exporter, accounting for 15 percent of global agricultural exports (Gehlhar and Vollrath, 1996). In addition, U.S. agricultural trade recorded a surplus of \$30 billion in 1996, contributing 10 percent of the country's total export earnings. Nevertheless, the returns to factors of production in agriculture—such as farmland, family labor, farm equipment and buildings—have grown only 1 percent per year (on average) since 1959, while the returns to labor and capital (GDP) at the national level have grown at almost 3 percent (Gopinath and Roe, 1995a).

The U.S. agricultural sector has both maintained its presence in international markets and declined in importance within the U.S. economy. This raises several questions about U.S. agriculture and its interaction with the broader economy. What factors account for the growth of U.S. agriculture? How does agricultural growth compare with other sectors of the U.S. economy? Does the growth of agriculture

benefit the broader economy and, in particular, the food processing sector? Can the United States continue to compete with European and other countries in increasingly competitive world agricultural markets?

In what follows, we provide some background on U.S. agriculture before proceeding to address each of the above questions. Productivity growth, or increases in output per unit of input, is crucial for agriculture. Productivity growth is a broader concept than partial productivity measures like labor productivity or yields. Increasing fertilizer (labor, land, machinery) use can increase output but not necessarily output per unit of input; as more of a particular input is used, its contribution to additional output declines. The level of output per unit of input is often referred to as total factor productivity (TFP) or the level of technology (Ahearn et al., 1998).

Agricultural prices have been falling relative to the prices of nonagricultural commodities. This ratio (an index of agricultural prices to an overall price index for the goods and services produced in the U.S. economy such as the GDP deflator) we call the terms of trade of agriculture.

The returns to factors engaged in agricultural production depend upon the growth in TFP within agriculture and changes in agriculture's terms of trade with the rest of economy. Since the late 1940's, the rate of growth in U.S. agricultural TFP has averaged around 2 percent per year (Gopinath and Roe, 1995a; Ahearn et al., 1998). This rate of growth has driven the growth in agricultural output (2.16 percent per year), while at the same time preventing further declines in returns to the factors of production. Public investments in agricultural research and devel-

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This paper summarizes and highlights the key results reported in several other papers produced as part of a research project on U.S. agricultural competitiveness in global markets. See Project Output for the list of reports.

opment (R&D) and public infrastructure account for 75 percent of the growth in agricultural TFP. However, the growth in public agricultural R&D has declined from about 6 percent per year in the 1960's to under 2 percent per year in the 1990's (Alston and Pardey, 1996). This raises concern about the future growth of U.S. agriculture since, as other research suggests (Ruttan, 1996), sustained investment in R&D is required just to maintain current yields from the coevolution of pests and pathogens.

Although the total number of farms has declined, farms with sales of more than \$100,000 per year continue to grow in number and resource use (fig. 1). This suggests that the commercial farm sector continues to grow and to account for increasing shares of agricultural output (fig. 2). However, employment in

the sector has declined relative to other sectors of the economy. The reduction in the number of farms is associated with the decline in agriculture's terms of trade, which has offset, to a considerable degree, the beneficial effects of TFP growth on agricultural GDP. Agricultural TFP growth has stabilized since 1985 (Gopinath and Roe, 1995a), along with a decline in the rate of growth in public investments in agricultural R&D. No historical evidence is available to suggest that private sector investments in agricultural R&D are alone sufficient to mitigate the negative effects of price declines on the returns to resources specific to agriculture.

Markets for many basic agricultural technologies (such as research in plant breeding, plant pathology, soil physics and chemistry, and animal nutrition) con-

Figure 1

Farms below \$100,000 decline while those above \$100,000 increase

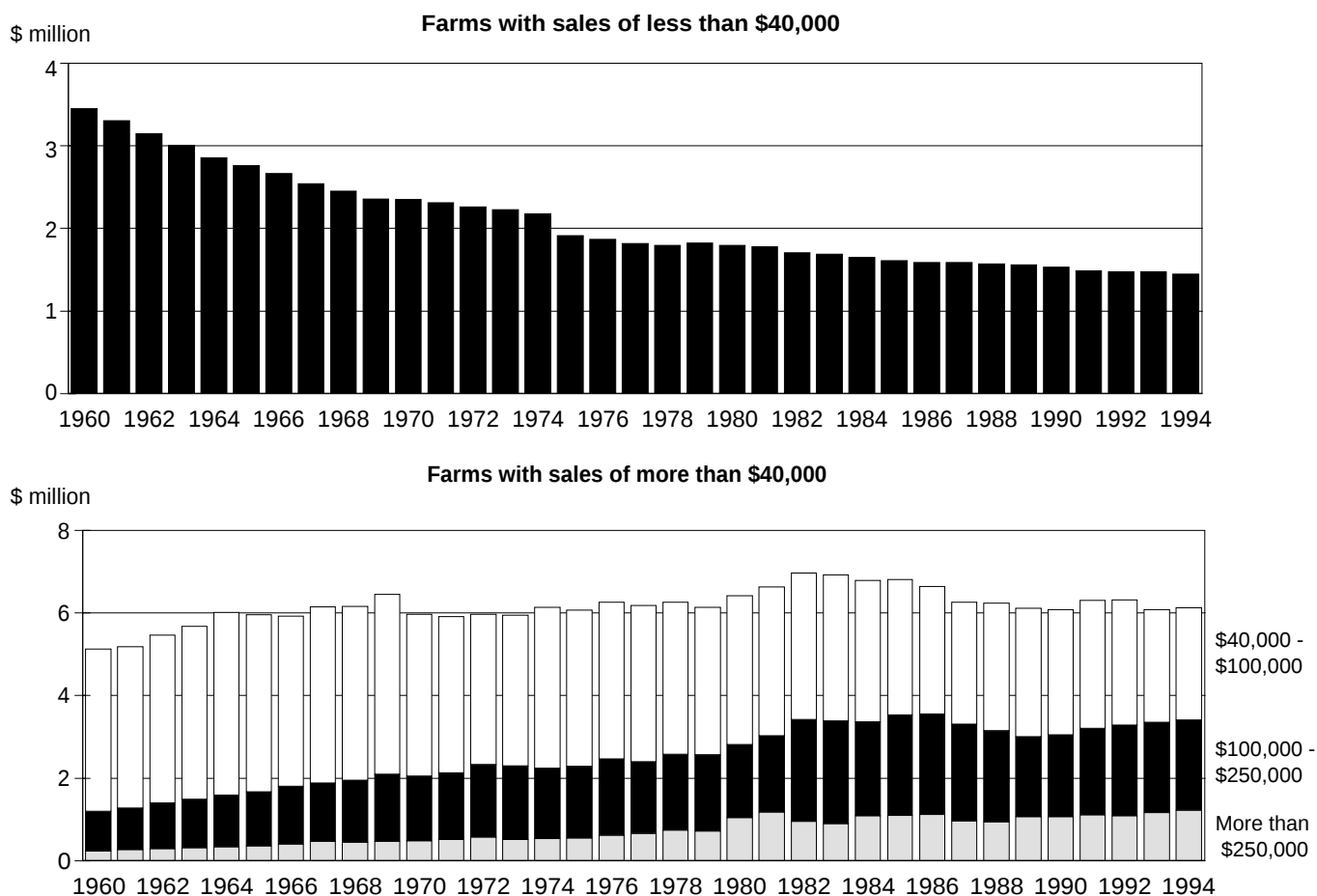
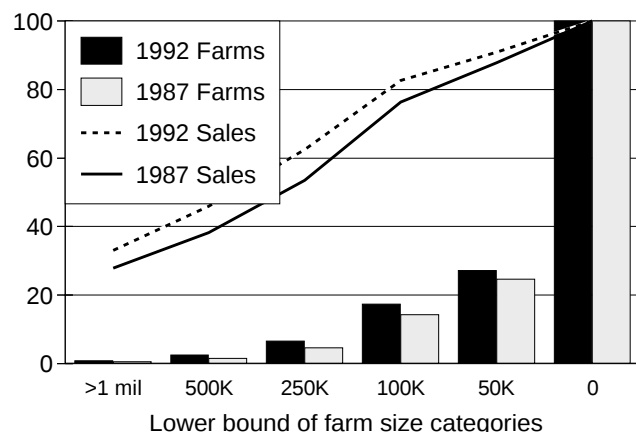


Figure 2

Commercial farms are producing an increasing share of farm output

Percent of sales and farm numbers



tain a large public good component (Huffman and Evenson, 1993; Alston and Pardey, 1996). Thus, returns realized by private R&D firms investing in this type of research fall far short of the full contribution to productivity. Consequently, private sector firms tend to underinvest in these activities and rely on the public sector for this type of basic research. They then adopt and adapt the more basic research to specific local and regional market conditions.

Productivity growth and public investments in agricultural R&D have important implications for the

broader economy and, in particular, for the food processing sector. U.S. agriculture provides primary agricultural inputs to the food processing sector at declining real prices (Gopinath, Roe, and Shane, 1996). These lower prices, in turn, are passed on to the rest of the economy in terms of moderately lower real prices for processed foods. This cost advantage allows the processed foods sector to compete more effectively for export shares in the growing world markets for processed food. Hence, growth in agricultural productivity increases the returns to the factors engaged in agricultural production, while at the same time these gains in efficiency are shared with the rest of the economy. This also suggests that declines in the growth of public investment in agricultural R&D may lead to reduced rates of growth in the food processing sector and encourage increased imports of processed foods.

Sources of Growth in the U.S. Economy and Agriculture

We first examine the sources of growth in the overall economy. This analysis shows the evolution of the major sectors of the U.S. economy, linkages among them, and the relative importance of productivity growth in agriculture and food processing.

Our methodology—unlike traditional approaches that use either production functions (Ball et al., 1996) or value-added functions (Jorgenson et al., 1987)—uses a GDP function to account for growth at the aggregate as well as sectoral level. In all these approach-

Table 1—Components of U.S. real GDP growth, 1959-91

	GDP growth	Price effect			Labor	Capital	TFP growth
		Agricultural	Manufacturing	Services			
		Percent					
1959-91 average	2.92	-0.03	-0.23	-0.35	1.18	1.18	0.40
% contribution		(-1)	(-8)	(12)	(41)	(40)	(16)
1959-62	3.00	0.00	-0.34	0.58	0.49	0.97	1.26
1963-67	4.77	-0.01	-0.09	0.22	2.02	1.64	0.92
1968-72	2.98	0.02	-0.31	0.39	0.88	1.45	0.53
1973-77	2.64	-0.02	0.17	-0.11	1.36	1.22	-0.01
1978-82	1.28	-0.06	0.05	0.14	0.98	1.28	-1.10
1983-87	3.85	-0.08	-0.64	0.75	1.74	1.00	1.03
1988-91	1.91	-0.04	-0.48	0.49	0.62	0.70	0.60

es, productivity growth is measured as a Solow residual—the ratio of growth in an index of aggregate output to growth in an index of aggregate input.

Ordinarily, productivity growth is the unexplained part of the growth in the index of aggregate output. However, our GDP function approach extends the production function approach by taking into account agriculture's terms of trade with the rest of the economy and its competition with other sectors for economywide resources.

Sources of Growth in the U.S. Economy

Real growth in U.S. GDP averaged 2.92 percent per year over 1959-91. At this rate, it takes approximately 24 years to double the current level of GDP. Increases in inputs, labor, and capital (accumulation) have accounted for more than 80 percent of the growth in real U.S. GDP, while productivity growth, at 0.40 percent per year, accounts for only 16 percent (table 1, Gopinath and Roe, 1996). However, the nature and magnitude of these effects have varied substantially among sectors.

The growth of the services sector has benefited most from favorable changes in relative prices (fig. 3), while manufacturing, agriculture, and food processing have suffered negative terms of trade. These varying fortunes did not affect the rate of growth in overall U.S. GDP, because gains to one sector are offset by losses to other sectors (Gopinath and Roe, 1996). Nevertheless, changes in terms of trade had

large effects on sectoral outputs. The increases in the real price of services accounted for 56 percent of the growth in the services sector share of GDP. The analysis also found evidence of some price complementarity between agriculture and manufacturing: an increase in the price of manufacturing leads to a small increase in the supply of agricultural output. This result is explained, in part, by agriculture's being a supplier of primary inputs to the manufacturing sector.

While productivity in the overall U.S. economy has been growing throughout the post-war period (Gopinath and Roe, 1995b), the impact of productivity growth has not been uniform across all outputs. The sectoral bias in productivity growth has favored the production of services relative to manufacturing. Our empirical results also suggest that technological change has been biased toward augmenting the productivity of labor relative to that of capital. It is not surprising that the bias in favor of the services sector arises from growth in labor productivity because it is a relatively labor-intensive sector. Interestingly, no bias was found for the case of agriculture, although labor use declined at an average rate of 1.8 percent per year since 1945. At the aggregate level, the effect of technology on agricultural output has been neither positive nor negative; productivity growth within the sector is just sufficient to overcome the large bias of labor-using technological change that benefited the services sector. Thus, the growth of the

Figure 3

Food processing and agriculture face most severe price declines

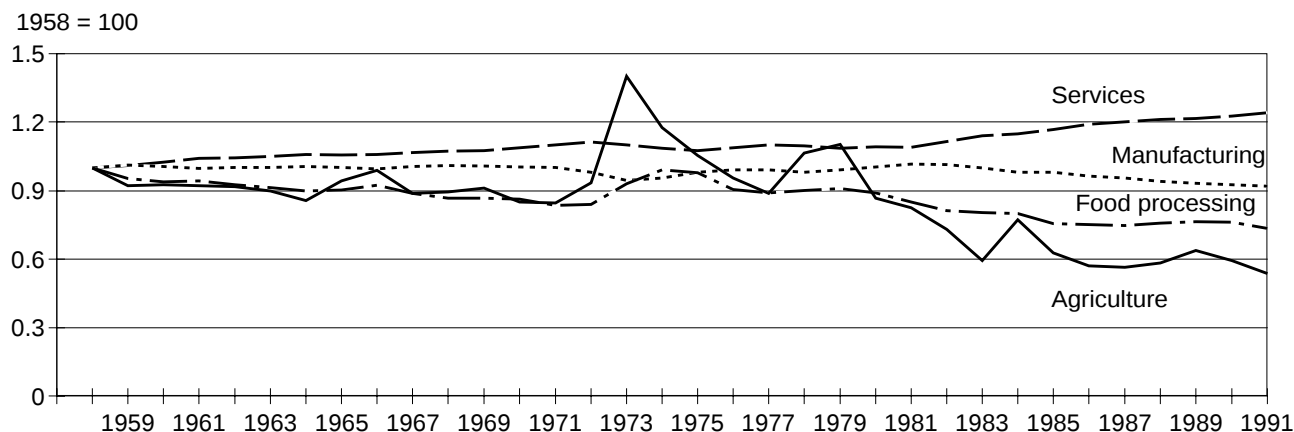
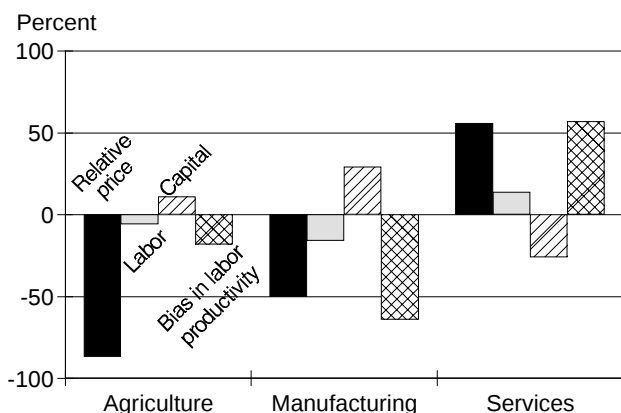


Figure 4

Factors contributing to changes in sectoral shares of GDP, 1948-92



U.S. economy is characterized by an increase in the share of resources allocated to the production of services relative to agriculture and manufacturing (fig. 4). This has dampened the growth in returns to resources specific to the agricultural sector, while helping to increase returns to labor caused by the growth of the service sector.

Agricultural Growth

Growth in real primary agricultural GDP derives from changes in the level of real agricultural prices, changes in the level of inputs, and growth in TFP.¹ Increases in inputs and output prices typically increase production, but do not necessarily increase productivity. As Krugman (1996b, p. 171) notes, “productivity growth represents increases in output per unit of input; such increases may result from better management or better economic policy, but in the long run are due to increases in knowledge,” as embodied in new technologies and management know-how. However, the nature and magnitude of all three effects—prices, inputs, and productivity—on growth are important as each of them can be influenced by public policy.

Agricultural output growth averaged 2.16 percent per year between 1959 and 1991, while real agricultural

¹In this report, the terms “productivity” and “total factor productivity” are used synonymously.

Table 2—Components of U.S. agricultural real GDP growth, 1959-91

	Real Agri. GDP growth	Real price effect	Input contribution	TFP growth*
Percent				
1959-91 average	0.97	-1.19	-0.15	2.31
1959-63	0.14	-2.40	0.00	2.54
1964-68	0.39	-1.95	-0.69	3.03
1969-73	8.97	5.71	-0.19	3.45
1974-78	-2.73	-4.18	1.99	-0.54
1979-83	-4.56	-2.86	-1.45	-0.25
1984-88	0.78	-2.17	-1.21	4.16
1989-91	5.65	0.03	0.94	4.68

*The sum of TFP growth (2.31) and input contribution (-0.15) yields the traditional output growth (2.16).

GDP grew at only 0.97 percent per year (table 2, Gopinath and Roe, 1995a).² The difference (-1.19 percent) is explained by the decreasing real prices for agricultural output.³ A decline in the level of total inputs employed in agriculture also contributed to the decline in the growth in its real GDP (-0.15 percent per year). Intermediate inputs, such as better seeds and chemicals, contributed positively to growth (0.49 per cent per year), but this contribution was insufficient to overcome the effects caused by the exit of labor (table 3, Gopinath and Roe, 1995a). The contribution from capital and land to growth was also small.

TFP growth is the major contributor to growth in agricultural output and to the returns to its sector-specific factors of production. Growth in TFP averaged 2.31 percent per year over 1959-91 (table 1, Gopinath and Roe, 1995a); as estimated by ERS, TFP growth in primary agriculture was 1.94 percent for 1948-94 (Ahearn et al., 1998). The difference is largely due to our approach, which accounts for the

² Agricultural output is measured by a quantity-based index with fixed base-year prices, while real agricultural GDP is a value-based series of agricultural GDP, taken from the national income accounts, divided by the GDP price deflator.

³ There are several reasons for agriculture’s falling terms of trade. In a global context, productivity growth has led to supply shifts outpacing demand, which has resulted in declining agricultural prices. Low price and income elasticity of demand for food may also lead to declining prices.

Table 3—Components of agricultural input growth, 1959-91

	Hired labor	Family labor	Intermediate inputs	Real property	Capital	Aggregate input
	<i>Percent</i>					
1959-91	-0.14	-0.39	0.49	-0.08	-0.03	-0.15
1959-63	-0.06	-0.83	0.97	-0.04	-0.03	0.00
1964-68	-0.67	-0.61	0.47	-0.02	0.14	-0.69
1969-73	0.02	-0.39	0.03	0.05	0.09	-0.19
1974-78	0.05	-0.47	2.09	0.12	0.21	1.99
1979-83	-0.12	-0.25	-0.30	-0.61	-0.18	-1.45
1984-88	-0.06	-0.31	-0.51	-0.02	-0.33	-1.21
1989-91	-0.20	0.49	0.78	-0.02	-0.11	0.94

effects of falling real prices for agricultural commodities. At this rate of TFP growth, aggregate agricultural output would double in about 30 years, holding all else constant. Although TFP growth in the last column of table 2 exhibits high variability, the filtered TFP growth series suggests a stagnating trend since 1980 (Gopinath and Roe, 1995a).⁴ If productivity had instead grown by only 1.34 percent, then returns to resources specific to agriculture would have remained constant over the period.⁵ Stagnant returns would almost surely have encouraged more resources to exit agriculture and flow into other sectors of the economy. Hence, productivity growth in agriculture is crucial to sustaining the returns to its sector-specific resources, given agriculture's declining terms of trade with the rest of the economy.

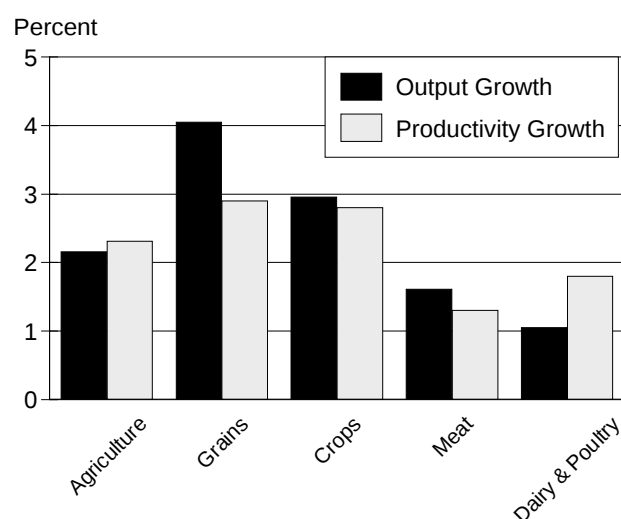
These aggregate effects of prices, inputs, and productivity on agricultural growth have concealed the reallocation of resources among subsectors (Gopinath and Roe, 1995b). While the outputs of grain, crop,⁶ and livestock outputs have all grown, the bias of productivity growth has been toward grains and crops relative to livestock (fig. 5). Since grain production is far less labor-intensive than livestock, rising real wages caused by the growth of the services sector places larger upward pressures on the cost of live-

stock production than on grain production. Moreover, the higher rates of productivity growth in the grain and crop subsectors have, at the margin, helped them to pull resources from the livestock sectors. As the grain and crop subsectors are more intensive in the use of intermediate inputs (fertilizers, pesticides), they have also benefited from technological change embodied in these inputs.

Growth in the Food Processing Sector

The growth in real GDP of the food processing sector, at 1.04 percent per year, averaged slightly more

Figure 5
Output and productivity growth rates in agriculture, 1949-91



⁴ The filtering was done to capture the underlying growth component in this series, which is devoid of fluctuations due to weather and related shocks. See fig. 9 for the trend of filtered TFP growth.

⁵ 1.34 percent represents the combined effects of declining real prices and input use (1.19+0.15).

⁶ The crop category does not include food and feed grains.

Table 4—Components of U.S. food processing real GDP growth, 1959-91

	Food proc. GDP growth	Real price effect	Input contribution	TFP growth
	<i>Percent</i>			
1959-91 Average	1.04	-0.83	1.46	0.41
1959-63	0.95	-1.79	1.84	0.95
1964-68	1.61	-1.03	2.34	0.34
1969-73	3.52	1.54	1.46	0.53
1974-78	1.84	-0.51	2.64	-0.23
1979-83	-1.46	-2.27	-0.09	0.95
1984-88	0.78	-1.15	1.14	0.81
1989-91	-0.64	-0.94	0.59	-0.28

than that of primary agriculture over 1959-91 (table 4; Gopinath, Roe, and Shane, 1996). Intermediate inputs were the major contributors to the growth of GDP in the food processing sector. All else constant, the contribution from all inputs to growth in its real GDP averaged 1.46 percent per year, with intermediate inputs alone (which include primary agricultural output) contributing 1.01 percent per year. Growth in total factor productivity averaged 0.41 percent per year. These two sources, together, yield an average annual rate of growth in the sector's output of about 1.87 percent. However, like primary agriculture, this sector too was subject to declining real prices (0.83 percent per year).

Primary agriculture averaged about 26 percent of the intermediate inputs used by the food processing sector over 1959-91. It follows that approximately a fourth of the growth in the food processing sector's GDP is attributable to the primary agricultural component of intermediate inputs. The drop in the primary agricultural price index of 1.19 percent per year translates into a decline of 0.32 percent per year in the total procurement costs of the food processing sector. Thus, productivity growth in primary agriculture is passed on to the food processing sector through reduced cost of primary inputs. However, prices for processed foods declined, on average, 0.83 percent per year. The net decline (0.51 percent) comes from within the sector and exceeds the rate of productivity growth (0.41 percent) in food processing. Consequently, productivity growth of both pri-

mary agriculture and food processing are passed on to consumers in the form of lower food prices.⁷

In contrast to primary agriculture, the contribution to growth of the food processing sector from changes in the level of inputs is relatively large. Arnade and Gopinath (1996) found that adjustment of the sector-specific capital in agriculture and food processing to changes in relative prices of output is slow because employment opportunities outside of agriculture are limited, particularly over short periods of time.

Thus, agricultural capital requires a long time before adjusting to a change in market conditions.

However, the food processing and services sectors' capital fully responds to any given change in external factors within 5 years. These observed differences in capital adjustment rates are consistent with capital's contribution to sectoral growth. In sectors like services and food processing, capital's contribution to GDP growth is relatively large, while it contributes under 3 percent to the growth in agricultural GDP. This brings to light, again, the importance of productivity as a major source of growth in U.S. agriculture. Productivity growth in U.S. agriculture not only sustains the returns to factors engaged in U.S. agriculture but also benefits the broader economy as efficiency gains are passed on to consumers as lower food prices through the food processing sector.

In the next section, we show that the rate of productivity growth in U.S. agriculture is lower than that of major European competitors. However, it is relative productivity growth (agriculture to nonagriculture) that is relevant for agriculture's export performance. Using this measure, the United States has a clear comparative advantage in agriculture.

How Does U.S. Agricultural Growth Compare With That of European Competitors?

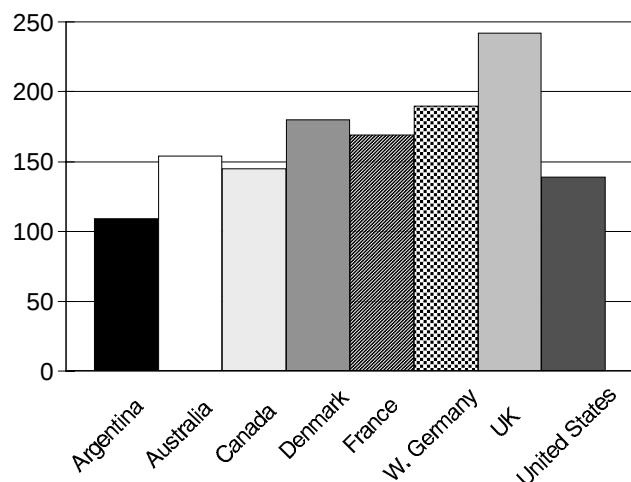
Growth in European agricultural output has been relatively high over the past few decades (fig. 6), and coincident with the EU's support for agriculture (Arnade, 1997; Bureau et al., 1995; Ball et al., 1996).

⁷ In an open economy like the United States, the downward pressures on processed food prices are likely to forestall import competition from other countries.

Figure 6

Productivity comparisons, 1965-86

Index basis



Growth in productivity, particularly in the 1970's, has been higher in European agriculture than in U.S. agriculture. In the 1980's, the gap between the rates of productivity growth declined.⁸ There are two hypotheses about growth in EU agriculture: (1) growth has been stimulated by high and stable prices that producers received under the European Union's Common Agricultural Policy (CAP); and (2) agricultural GDP growth in the EU has been the result of technological change. Our results suggest both factors played a part.

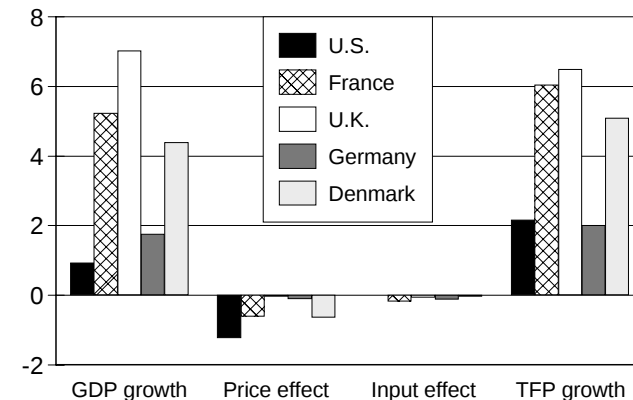
We decompose growth in agricultural GDP for four countries, Denmark, France, Germany, and the U.K., using the same growth accounting methodology applied to the analysis of the United States. Our results (Gopinath et al., 1996) indicate that productivity is the primary source of growth in agricultural output in these countries (fig. 7), as it was for the United States. Overall, the decline in real agricultural prices in Denmark, France, and the U.K. was smaller than that experienced by U.S. producers, and thus, the negative price effects on their agricultural

⁸ Our results on growth rates differ from that of Ball et al. (1996), although the underlying patterns are similar. We attribute the differences to our methodology and data. We use the GDP function approach for comparisons with the United States, while Ball et al. used a production function approach. Our data are derived from SPEL database by aggregating over 32 crops and 20 inputs. Ball et al. (1996) derived data from the European Accounts for Agriculture (OECD).

Figure 7

Components of GDP growth in the United States and major EU countries, 1974-93

Percent



sector's GDP were less significant than for the U.S. case.⁹ EU agricultural policies through about 1988 appear to have insulated its agriculture from the global decline in real prices. Since 1988, the negative effects of price declines on EU agriculture's GDP have been relatively large, but still smaller than those for the United States (Gopinath et al., 1996). Accompanying the negative price effects is a fall in EU agriculture's rate of productivity growth. Together, these two effects have substantially lowered the four countries' growth in agricultural GDP, particularly in recent years.

All else constant, the level of a country's exports depends not on absolute but on comparative productivity advantage.¹⁰ The assessment of changes in comparative advantage between two countries entails a comparison of the ratio of growth in agriculture to growth in the rest of the economy. Productivity growth is the dominant factor explaining output growth in both U.S. and European agriculture. The ratio of agricultural to nonagricultural productivity growth in the United States was about 10 (2.17 percent productivity growth in agriculture and 0.21 per-

⁹ Although the EU has a common agricultural policy (CAP), it is not necessary for CAP to have the same effect on all the economies. As the prices are relative to the other sectors of the economy, the price effects can be different for countries within the EU.

¹⁰ Input-driven growth is inevitably limited because mere increases in inputs must run into diminishing returns (Krugman, 1996). Growth through increases in efficiency/productivity is sustainable.

cent productivity growth in the entire economy) during 1974-91 (fig. 8). For the European countries, agricultural productivity growth ranged from about 7 percent for the U.K. to 2 percent for Germany. Economywide productivity growth rates varied between 1.7 percent for the U.K. to 2.9 percent for France (Boskin and Lau, 1992). This suggests that the ratio of agricultural to nonagricultural productivity in major EU countries is between 1 and 4. Based on these comparisons, U.S. agriculture appears to have a fundamental comparative advantage in world markets relative to the EU largely because of its relative technological progress.¹¹

Sources of Productivity Growth

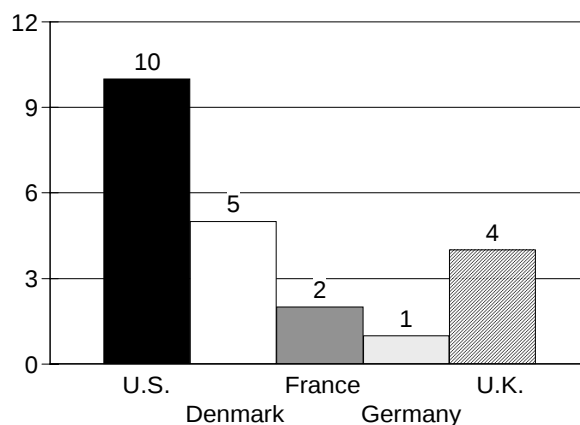
Longrun increases in productivity growth can, for the most part, be traced to increases in organizational and technical knowledge (Krugman, 1996a,b). While resources are required to create organizational and technical knowledge, it is commonly accepted that markets for knowledge, even outside of agriculture, tend to be imperfect because the returns realized by an inventor fall far short of the invention's full contribution to productivity. Knowledge is a nonrival good in the sense that its use by one does not preclude its use by another. In addition, the partially nonexcludable nature of knowledge poses difficulty for its creators/owners in capturing the value of their invention's "total" contribution to future productivity. This includes future inventors' partial use of the knowledge embodied in the given invention to invent a new technology or process. In other words, an incremental increase in knowledge as reflected in a new patent or a trade secret tends to generate new ideas and additional patents. These new ideas, which are partially rooted in the initial patent, also provide an incremental increase in new knowledge that not only increases the productivity of firms within the sector but throughout the economy. Bernstein and Nadiri (1988) and Gopinath and Roe (1997) suggest such technological spillovers are relatively large for the industrial and agricultural sectors in the United

¹¹ This is consistent with the results of Gehlhar and Vollrath (1996) on U.S. export performance in agricultural markets. The U.S. share of world agricultural markets has grown by 1.3 percent per year beginning in 1987, while the EU share has stayed constant.

Figure 8

Relative productivity growth

Agricultural TFP/
Nonagricultural TFP



States. As the initial inventor is unlikely to receive payments for these upstream inventions, the financial incentives to allocate resources to R&D activity are lower than those socially desired.¹²

Over 1949-91¹³, productivity growth in agriculture can be attributed to four major factors: public investment in agricultural R&D, public expenditures on infrastructure, private investment in R&D, and technological advances embodied in material inputs such as fertilizers and chemicals (Gopinath and Roe, 1995a). Public investment in R&D accounted for an average of 50 percent of productivity growth in agriculture over 1949-91 (fig. 9). However, public investment in R&D affects TFP growth with a considerable lag that averages 15 years. Thus, the relatively large contribution to growth in agriculture's TFP noted during the 1980's is largely due to investments made in the 1960's and 1970's. As we note below, the rate of growth in public investment in agricultural R&D has fallen significantly in recent years.

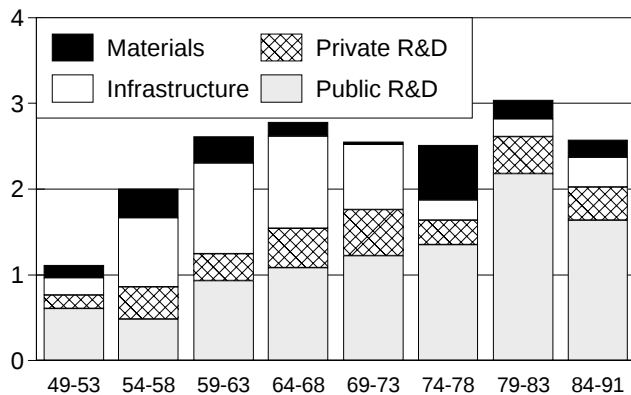
¹² This condition is often referred to as market failure, where markets fail to reward the innovator the full returns to his/her innovations.

¹³ This part of the analytical work was done with a longer time series. Productivity growth comparisons within the U.S. economy and within the EU were restricted to shorter time periods (1959-91 and 1974-91) because of lack of data for earlier periods for the food processing sector and the EU, respectively.

Figure 9

Contributions to agricultural TFP growth, 1949-91

Percent per year



The empirical link between public R&D and productivity growth is measured as changes in the cumulative stock of public R&D, an index of the stock of scientific knowledge.¹⁴ Similarly, an index of public infrastructure measured by cumulating public investments in services—such as highways, rural roads, and public utilities—accounted for another 25 percent of productivity growth in agriculture over 1949-91. Private R&D and the productivity embodied in intermediate inputs together accounted for the remaining 25 percent.

Public R&D has become an increasingly important factor in agricultural TFP growth over time (fig. 9). Infrastructure was more important in the early periods than the later periods, reflecting the large investments in interstate highways and other public utilities during the 1950's and 1960's. Private R&D makes a consistent but smaller contribution to productivity growth.¹⁵ This reflects the fact that most of the effi-

ciency gains from private investments in R&D are paid for by farmers purchasing the intermediate factors that embody the technology. Thus, the effects on growth in primary agriculture's real GDP caused by private R&D investments are largely captured by our measure of the level of intermediate input use.¹⁶

Public investment in agricultural R&D has been estimated to have a high social rate of return.¹⁷ Nonetheless, the growth in public spending on R&D has stagnated since the early 1970's (fig. 10). During the 1980's, research expenditures in developed countries grew at only one-quarter the rate experienced during the 1960's (Alston and Pardey, 1996, p. 47). Studies of public investment in U.S. agriculture conclude that the social returns from these investments range from 25 to 75 percent per year (Fuglie et al., 1996). Furthermore, private sector spending has been found to be complementary to public sector spending on agricultural R&D (Gopinath and Roe, 1995a). The development of the fundamentals of new agricultural technology by the public sector provides private opportunities to refine and adapt these technologies to particular environments and circumstances. Thus, a decline in the growth rate of public investment may also lead to a drop in private R&D.

Investment to enhance productivity growth (knowledge creation) is sensitive to the structure of an industry. It is likely that underinvestment by private firms occurs in technologies for which it is difficult to exclude use by others. For instance, U.S. seed companies pursue new hybrid varieties of corn far more intensively than high yielding varieties of wheat because the excludability of hybrid corn requires that farmers purchase the seeds (hybrid varieties) every year. Failure to exclude others from using a technology, which is often the case with agri-

¹⁴ Following Huffman and Evenson (1993), this stock is measured by cumulating public investments in R&D over a 30-year period. However, as investments vary in use over time, the annual investments were weighted differently (perpetual inventory method). For instance, an investment in 1960 contributes little to the R&D stock for the first 10 years, contributes the most during the next 10 years, and then declines toward zero by 1990 (trapezoidal density). The presumption here is that one dollar invested in agricultural R&D in 1960 is as productive as a dollar of R&D invested in 1990.

¹⁵ It is often claimed that public R&D provides opportunities for the private sector to further develop and adapt technologies to specific niche markets.

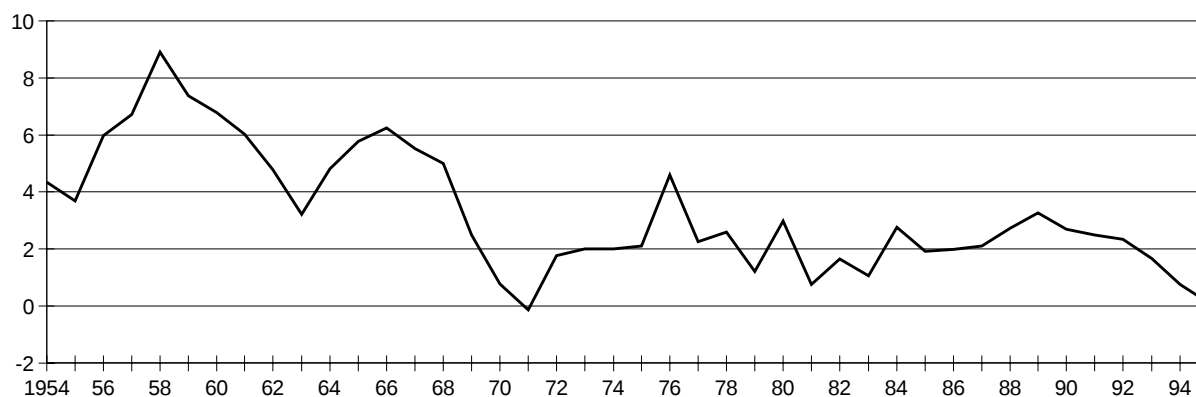
¹⁶ TFP, as measured here, is capturing sources of factor productivity growth that are largely produced elsewhere, e.g., from public R&D, and not from sources within the firm per se. TFP growth in primary agriculture may also induce efficiency gains in other sectors, for example, due to the production of a more homogeneous and higher quality product that lowers processing costs. These additional gains are not accounted for in our analysis. Returns from investments that are internal to the firm are captured as returns to the factors of that firm.

¹⁷ A full exposition of this issue is beyond the scope of this paper. See Fuglie et al. (1996) and Alston and Pardey (1996) for more details.

Figure 10

U.S. public agricultural R&D growth rates, 5-year moving average

Percent (in 1992 dollars)



1954 value represents average over 1950-54.

Source: Alston and Pardey, 1996; and USDA.

culture, is more likely in competitive industries producing nearly homogeneous products.¹⁸

Thus, is there a high degree of externality to public investments in agriculture so that the public and private returns to the investment differ by a large margin? In other words, do the public good properties of agricultural technology create a divergence between private and social benefits? Given the large number of relatively small firms and the significant overhead involved in agricultural research, the potential returns to a single entity are small compared with the potential for the industry. The recent strengthening of legislation to protect the intellectual property rights of biological inventions has helped in the creation of new technologies, but it is still not likely that the benefits of new technologies will not benefit others outside the inventing organization. Evidence suggests that private returns to R&D differ significantly from the social rate of return, leading to underinvestment in private R&D (Bernstein and Nadiri, 1988; Gopinath and Roe, 1997).

Since agricultural products are subject to both inelastic demand and Engel's law (declining share of household expenditures as income increases), the longrun beneficiaries of productivity growth are con-

sumers, who are able to purchase food and fiber at ever-declining real prices. Agricultural research has high social benefits, but they are not easily captured by the private sector. On average, over 1959-91, productivity growth in agriculture has largely been offset by the decline in prices, leading to a net growth in the sector's real GDP of only 0.97 percent per year (Gopinath and Roe, 1995a).¹⁹ Overall, societal benefits have grown since the sector's productivity gains are coincidental with its declining real prices (fig. 3).

Industries that produce nonhomogeneous commodities, like food processing, are typically able to capture higher returns from private investments in R&D. Firms in these sectors often produce a unique or differentiated product for which they can extract "excess rent" by charging a price above the marginal costs of production. The excess rent can be viewed as a return to either the patent protecting the idea or the trade secret embodied in the commodity. Rents, in this case, may be reinvested by the firm in R&D activities that lead to developing a new, lower cost cake mix or breakfast cereal. Effectively, firms producing differentiated products can, in principle, internalize the benefits of R&D to a greater degree than firms producing homogeneous products. Thus, the

¹⁸ For the same reasons, there is likely to be underinvestment in environmentally sustainable technologies.

¹⁹ There are clearly other sectors which have experienced declining real prices such as computers, other electronics, and communications, but private investment rates in these sectors are relatively high.

observed low rate of productivity growth in food processing may result from the development of new technologies, the cost of which we observe as investments appearing on the firm's balance sheet. In this case, our growth accounting procedure (Gopinath and Roe, 1995a) captures these effects on growth as input effects.²⁰

Conclusions

Growth in U.S. agricultural productivity benefits the broader economy in three ways. First, productivity growth is the dominant factor explaining growth in agricultural output in the United States. TFP growth has offset the negative effects of agriculture's declining terms of trade and, thus, has sustained returns to agricultural factors of production. Lack of growth in returns would almost surely have encouraged more resources to exit agriculture, which, in turn, would tend to lower growth in returns to family labor, farm buildings, land, and other sector-specific resources.

Second, real agricultural prices have declined at 1.19 percent per year since 1959, which has been passed on to consumers through the food processing sector. Growth in the food processing sector arises largely from its use of intermediate inputs. The share of primary agricultural output in the intermediate inputs of the food processing sector averaged 26 percent over the last three decades. The 1.2-percent fall in the real prices of primary agricultural outputs led to a decline of 0.32 percent per year, on average, in the procurement cost of intermediate inputs. This cost advantage should allow the processed foods sector to compete more effectively for export shares in the growing world markets for processed food. However, real prices of processed foods have also declined (-0.83 percent) more than the sector's rate of productivity growth (0.41 percent). Thus, food processing passes on almost all of its productivity growth and the gains from primary agriculture to further downstream sectors like food wholesale and retail industries, and eventually to consumers.

²⁰ Of course, an industry may instead choose to pay larger dividends. In this case, the interesting implication is that monopolistic behavior may be more socially profitable than the older Chamberlinian theories would suggest.

Third, although the rate of European agricultural TFP growth is larger than that in the United States, U.S. agriculture has a higher relative productivity—the ratio of agricultural TFP to nonagricultural TFP—suggesting that it has the comparative advantage in agriculture. Hence, sustaining productivity growth in U.S. agriculture is crucial for maintaining its share of world agricultural markets.

Investments in public agricultural R&D and public infrastructure accounted for 75 percent of the growth in agricultural TFP. However, although the rate of TFP growth in agriculture has continued at above-average rates since 1970, no further acceleration in the series has occurred since the late 1960's. Due to the time lag between new investments in public agricultural R&D and productivity growth, the current slowdown in TFP growth may be explained, in part, by the lower growth rate in public investments beginning in the 1970's. More problematic is the implication of continuing stagnation of public investment in agriculture on the future growth of the sector.

With declining real prices, growth in output and returns to factors of production in agriculture depend crucially on productivity growth. Moreover, TFP growth in primary agriculture helps maintain the competitiveness of the food processing sector by lowering its costs for primary agricultural commodities. The decline in real prices of agricultural commodities and processed food products are passed on to consumers. Thus, the social rates of return to public agricultural R&D, which leads to productivity growth, are found to be relatively high. This suggests that positive growth of public agricultural R&D investments should increase the living standards of farm households and sustain the U.S. competitive edge in foreign markets.

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