Agricultural Productivity: Trends and Implications for the Future

By Marvin Duncan and C. Edward Harshbarger

At a time when the U.S. economy is bedeviled by persistent price inflation, productivity increases can play a salutary role in dampening increases in production costs. Unfortunately, growth in productivity in the United States has slowed considerably in the past decade. During 1978, output per hour of all persons in the nonfarm business sector increased by a disappointing 1.1 per cent.

The situation in agriculture is somewhat brighter in that labor productivity continues to grow in excess of 6 per cent annually. However, labor productivity is increasingly regarded as an inadequate measure of productivity change in agriculture. A measure of total resource productivity is generally considered more appropriate. On this basis, overall productivity in agriculture has been growing at only 1 to 1.5 per cent annually in the past five years—less rapidly than the 2.6 per cent average annual growth rate for the past 25 years. Slower productivity growth not only contributes to domestic food price inflation, but also may result in U.S. farm products being priced out of export markets. Thus, a slowdown in productivity growth is a matter of considerable concern for policymakers and farmers alike.

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WHAT IS AGRICULTURAL PRODUCTIVITY?

When productivity in the nonagricultural business sector is discussed, it is customary to refer to changes in the output-to-labor ratio, often in the form of a productivity index which measures the goods and services produced per hour by all persons employed. Productivity used to be measured the same way in agriculture, as well. However, such a measure is now of limited usefulness because the labor input in agriculture has become much less important while other inputs have become much more important—chemicals and equipment, for example. Total labor used in U.S. farmwork declined from a high of 24.1 billion hours in 1918 to only 4.7 billion hours in 1977. Conversely, fertilizer use increased from 890,000 tons in 1918 to 22.1 million tons in 1977, while tractor numbers increased from 85,000 to 4.4 million during the same time period.[1]

Individual measures of productivity—such as farm real estate, farm labor, machinery,

[1] Actually, tractor numbers peaked at about 4.8 million units in 1965 and have declined since then. However, total tractor horsepower has continued to increase and in 1977 was 3.5 per cent greater than in 1965.

chemicals, and feed, seed, and livestock purchases--can still serve specialized uses since they illustrate quite vividly the substantial changes in resource mix that have occurred in agriculture over the past several decades (Chart 1 plots these trend lines for the 1930-1977 period). Although the amount of farm real estate used has remained relatively constant for several decades and the amount of labor used has declined dramatically, the amount of machinery, agricultural chemicals, and feed, seed, and livestock purchases has greatly increased.

Total inputs used in agriculture have increased 20 per cent since 1910, while total output has increased 179 per cent during the same period. Clearly, the advances in output are due to more than just an increase in the amount of inputs used. Rather, the inputs have been changed and have been used in more productive combinations. Thus, on balance, the most appropriate measure of productivity in agriculture is one that shows how effectively farmers are able to combine all the inputs of production to produce food and fiber. This measure will be more meaningful than those that represent the productivity levels of individual resources.

To measure changes in overall productivity, a comprehensive index of farm inputs and an index of farm outputs were developed by the U.S. Department of Agriculture.[2] The index of farm inputs measures the volume of inputs used in farm production each year and applies a constant price factor. The inputs used in constructing the index include all farm production expenses except for the interfarm sales of farm products and the farm value of feed, seed, and livestock purchases. The index of farm output measures the level of all farm output produced in agriculture within a given calendar year, but does not include certain farm products consumed on farms or goods produced on farms and used in further farm production.[3]

There are, of course, some limitations to the two indexes.[4] The input index is constructed entirely from secondary data and, consequently, is only as reliable as that data. The output index is based on data that are incomplete and subject to revision. Neither index adequately takes into account quality changes in the items being measured. Finally, due to lack of data, some minor farm products—perhaps as much as 5 per cent of farm output—are not included in the output index. Nonetheless, the indexes probably represent the best achievable figures given the data limitations.

The ratio of the index of output to the index of inputs yields a productivity measure that indicates the efficiency with which total inputs are used in the production of agricultural products—information which is of great importance to policymakers (Chart 2). Changes in productivity growth rates signal future changes in public welfare. To the extent that these signals are recognized and acted upon, the level of public welfare can be maximized over time.

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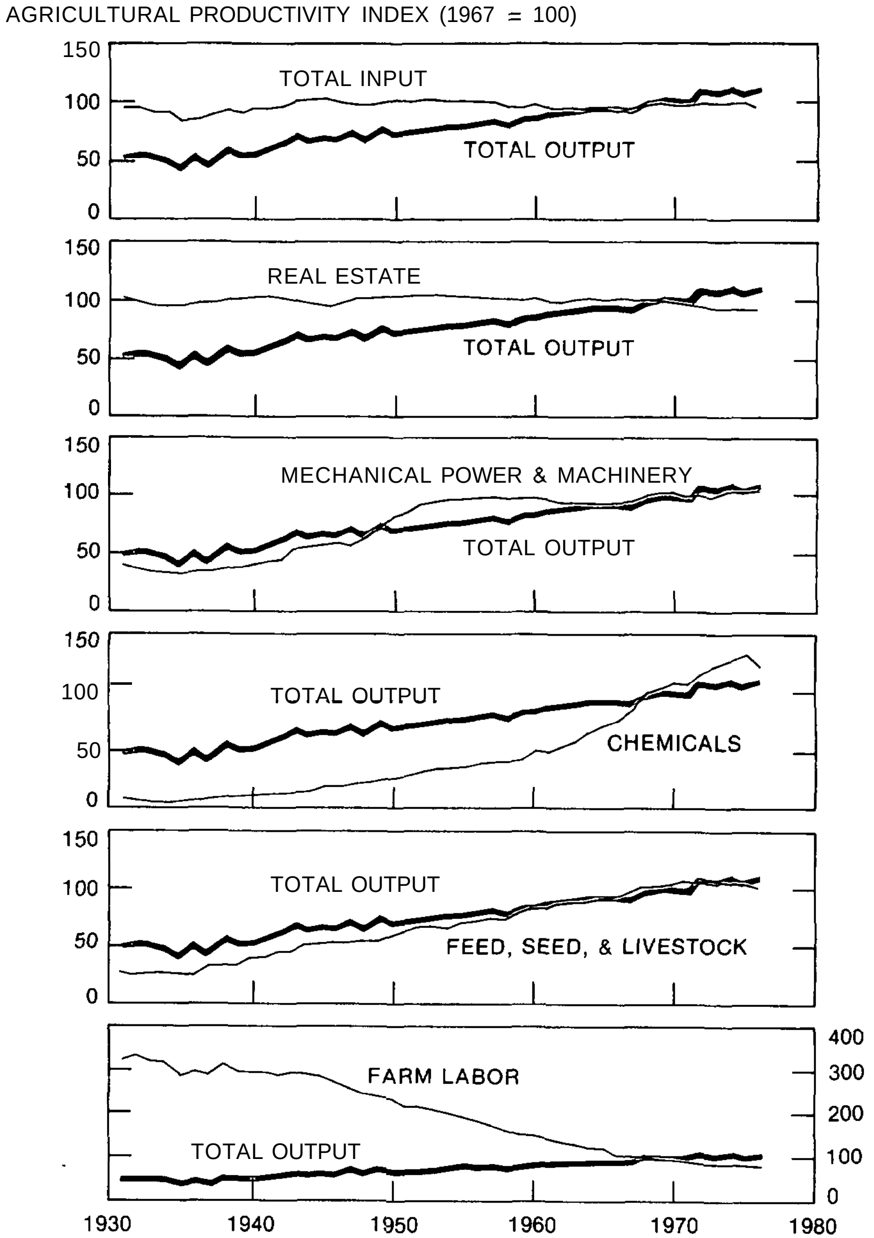
2 Ralph A. Loomis and Glen T. Barton, *Productivity of Agriculture. United States. 1870-1958,* Technical Bulletin No. 1238, U.S. Department of Agriculture, Washington, D.C., 1961.

3 *Major Statistical Series of the U.S. Department of Agriculture.* Vol. 2, Agricultural Handbook No. 365, U.S. Department of Agriculture, Washington, D.C., April 1970, pp. 15-20.

4 The indexes are calculated using a "weighted aggregate method." Quantities of inputs and outputs are multiplied by the average prices paid during a "weight base period." The indexes, then, combine inputs and outputs arithmetically, adding individual quantities weighted by their prices. Aggregate yearly totals are in constant dollars. In computing the index, yearly index numbers are expressed as a percentage of the index value in the base period. Separate indexes are also computed for a number of major farm input and output classifications.

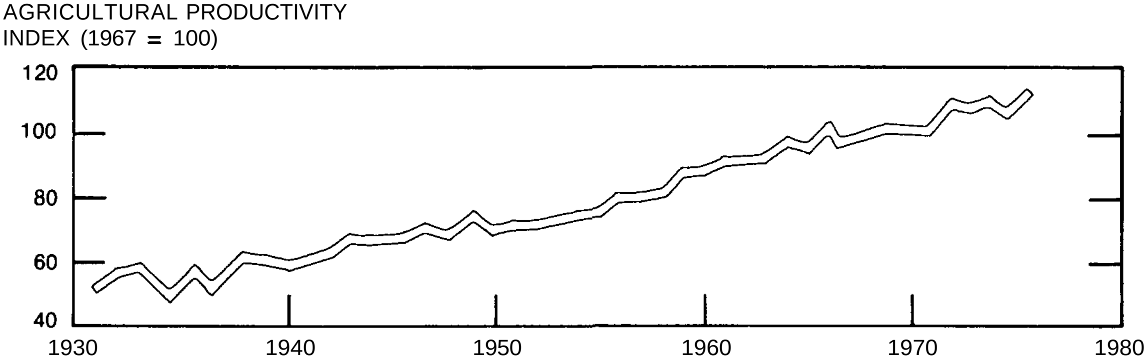
Chart 1

INDEXES OF MAJOR FARM INPUTS COMPARED TO TOTAL FARM OUTPUT, 1930-1977



SOURCE: U.S. Department of Agriculture.

Chart 2
AGRICULTURAL PRODUCTIVITY, 1930-1977



SOURCE: U.S. Department of Agriculture.

FACTORS CAUSING PRODUCTIVITY CHANGES

Productivity gains do not materialize out of thin air; they usually are only forthcoming some time after appropriate public and private policies are adopted. Productivity gains are also typically not smooth and continuous. Public and private investment may be required for some time prior to a payoff from such investment, as in the case of hybrid corn. Thus, while capital investment in efforts to achieve productivity increases must be substantial and continuous, the return on investment will typically be realized only after a delay.

Increases in agricultural productivity have been positively related to progress in the entire U.S. economy, but the causation runs both ways. A dynamic and prospering U.S. economy also benefits agriculture by providing healthy markets for agricultural goods, the technological and marketing innovations for both the inputs and products of agriculture, the resources with which to increase agriculture's productivity, and an attitudinal climate conducive to such activity.

Investment in basic and applied research also provides the technological breakthroughs that result in productivity increases. No other factor is so essential to increasing agricultural productivity as research. Substantial investment in basic research—often over a period of several years—is usually required before technological breakthroughs with practical applications are achieved. Agricultural pesticide and herbicide development, in which lead time of a decade or more is common, illustrates the need for long-term investment in research.

The rate of adoption of new technology is another important determinant of productivity change. New technology is of little value until put to a productive use. Both basic and applied education of the extension type are important facilitators of change because they tend to increase this adoption rate. The economic environment in which agricultural production takes place affects technology adoption rates, and profit opportunities spur input changes that either increase output or reduce cost. At the farm level, relative price changes among inputs can also result in rapid adoption of new technology.

A trend toward larger farms in the United States has played a role in productivity increases as well. Much of the new technology in agriculture has been adapted to meduim or larger sized farms, with the causation running in both directions. New technology has also increased labor productivity and enabled a farmer to handle more acres or head of livestock. Additionally, a larger scale of agriculture has permitted specialization in management and labor, another development aided by technology.

The pace of technological innovation by agribusiness firms on the input and product side of the market—as well as the adoption rate of new technology by farmers—is influenced by some additional factors. Profit opportunities are a powerful spur to the innovation and adoption of new tech-nology. Insufficient profits frequently mean decreased research efforts by many business firms as they tighten their belts. Reduced research and development budgets are likely to result in lower future growth in productivity. Environmental constraints, Government regulation, and product liability risk may cause the agribusiness industry to concentrate less of its budget on new product research. These same constraints may also slow the adoption rate of technology by farmers. On balance, present and future growth in productivity is heavily dependent upon a supportive economic, legislative, and regulatory climate.

Price inflation in the U.S. economy has likely had an adverse effect on productivity growth in and out of agriculture. Milton Friedman, in his Nobel lecture, contended that inflation makes a market economy less efficient by reducing the effectiveness of market prices in coordinating economic activity.[5] As investment patterns are distorted and savings rates decline, less financial commitment in real terms is typically made to research and development. In the past, public sector institutions have provided much of the basic research for agriculture. To the extent that inflation limits the capacity of these institutions to continue such research, slower productivity growth in agriculture will likely be forthcoming.

THE TRACK RECORD OF AGRICULTURAL TECHNOLOGY

While the productivity growth trend in agriculture has generally been accelerating since about the time of the Civil War, the major impetus for such growth has changed from time to time. After the introduction of new technology, productivity increases tend to be quite rapid, followed by a slowing in the growth rate after widespread adoption. Thus, new technology or innovation is required from time to time to spur productivity growth. Chart 3 illustrates total agricultural productivity growth during the past 200 years, which may be divided into four periods according to major sources of productivity increases: **1776** to the Civil War—human power, the Civil War to World War I—horsepower, World War I to World War 11—mechanical energy, and World War **II** to the present--early science power.[6]

Until the Civil War, productivity changes were principally related to making human labor more productive. A number of innovations occurred, such as the cotton gin, cast iron plows, and mechanical reapers, but there were no major technological breakthroughs. As a result, productivity grew rather slowly, leveling off about **1830** with little further growth until

5 Milton Friedman, "Nobel Lecture: Inflation and Unemployment," *The* Journal of Political Economy, Vol. 85, 1977, pp. 466-67.

6 Yao-Chi Lu and Leroy Quance, "Outlook for Technological Change and Agricultural Productivity Growth Through the Year 2000," *The* Future of Productivity. National Center for Productivity and Quality of Working Life, Washington, D.C., Winter 1977, pp. 37-49.

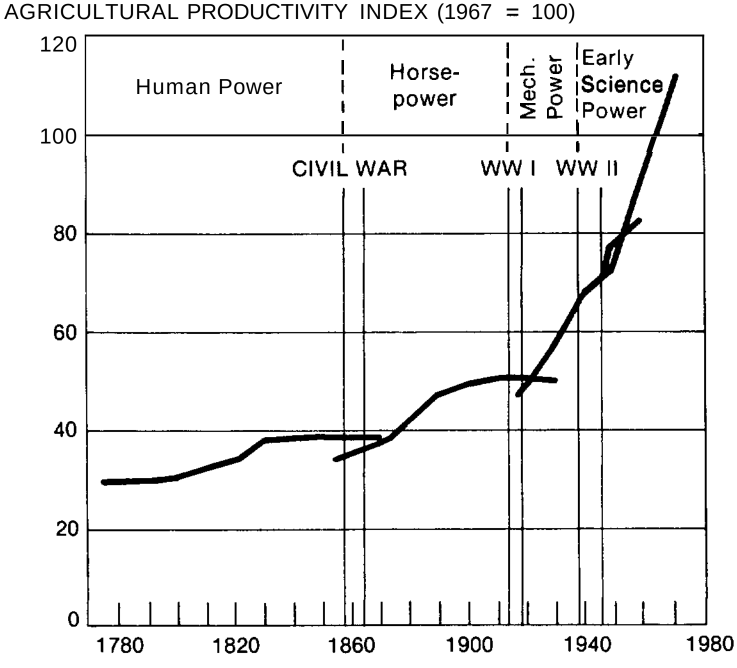
the Civil War.

Manpower shortages and high food prices, induced by the war, stimulated widespread adoption of horsepower machinery after 1860. Though much of the machinery had been invented earlier, the war resulted in economic conditions conducive to adoption of the new technology. Horsedrawn reapers, grain drills, corn shellers, and cultivators came into general use between the Civil War and the turn of the century. During the same period, public policy actively supported the generation of new farming knowledge and its distribution to farmers. The U.S. Department of Agriculture was established in 1862, along with land grant colleges in each state. The Hatch Act of 1887 established experiment stations in each state to develop new knowledge and technology, and the Smith-Lever Act of 1914 formed the Cooperative Extension Service to disseminate that knowledge and technology to farmers.

The mechanical power revolution got underway during World War I with the wider acceptance of gasoline-powered tractors by farmers. But it was not until the country began to climb out of the Great Depression that farm economics became favorable for a widespread surge in mechanization that lasted into the 1950s. This mechanization freed vast numbers of people from agriculture, and, as a result, both labor productivity and overall productivity soared.

Prior to widespread use of mechanical energy in agriculture, each new wave of technology

Chart 3
U.S. AGRICULTURAL PRODUCTIVITY GROWTH DURING THE PAST 200 YEARS



SOURCE: **The Future of Productivity,** National Center for Productivity and Quality of Working Life, Washington, D.C., Winter 1977.

had resulted in rapid productivity growth followed by declining growth rates as adoption neared completion. However, after World War II, a series of overlapping innovations continued to spur rapid productivity gains. Widespread use of improved hybrid corn and disease-resistant, highly productive cereal grain varieties were factors in the early science power revolution, as was the increased use of fertilizers and the beginning of chemical control of weeds and insects.

Nor were technological innovation and the dissemination of knowledge limited to crop production. Animal genetics, health, and nutrition advances, coupled with equipment innovations, meant that livestock production shared in productivity gains as it had not done previously. Hydraulic control, diesel power, and engineering improvements opened new opportunities for productivity gains as new equipment enabled even fewer farmers to perform their work in a more timely fashion than had previously been possible.

PROSPECTS FOR THE FUTURE

A Limit to Productivity Growth

Productivity gains in the early science power era of U.S. agriculture have been impressive. Yet, in recent years, agricultural productivity has slowed in comparison with the levels achieved in earlier periods when major technological breakthroughs were occurring. This slowdown is disturbing to policymakers because of the obvious implications for economic growth and inflation. If the trend should continue, not only would the welfare of the nation's farmers be reduced, but consumers could expect to pay even higher prices for food. Thus, many segments of the American economy have a strong interest in the future prospects for agricultural productivity.

The sources of future gains in agricultural productivity are not likely to differ greatly from those of the past. New technology has propelled agricultural productivity to ever higher levels during the last several decades. As before, the development and adoption of these new techniques depended heavily upon publicly supported research and extension programs for agriculture. Once the technology became available and farmers learned about its cost saving features, the transition to the new methods moved rather rapidly.

If the U.S. farmer is to continue increasing his productivity, essentially growing two blades of grass where one grew before, significant increases in public expenditures for research and extension programs will have to occur. According to one study, a 1 per cent increase in such expenditures will raise agricultural productivity by .037 per cent over a 14-year period.[7] Moreover, Lu and Quance show that between 1967 and 2000, agricultural productivity might rise 42 per cent if research and extension expenditures are increased 3 per cent per year, and 48 per cent if expenditures rise 10 per cent per year.[8] While the response to the added outlays may appear small, it must be remembered that a one-point gain in agricultural productivity is equivalent to almost $1 billion in agricultural output in today's economy. Another important point is that if new environmental, institutional, and legal constraints are introduced in the agricultural sector, even more research will be needed to maintain and improve current productivity levels.

Tomorrow's Technology: Any Surprises?

In 1975, the National Academy of Sciences

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[7] Lu and Quance, p. 43.

[8] According to Lu and Quance, public expenditures for agricultural research and extension amounted to about $740 million in 1971.

reported that a major scientific breakthrough similar to hybrid corn or DDT was not likely to occur within the next 10 to 20 years.[9] This observation suggests that agricultural productivity will continue to grow slowly in the years ahead. However, emerging technologies could have a significant impact on the productivity picture by the year 2000. In recent years, researchers have been working on a number of projects which promise to produce gains in productivity. These new ideas range from better management practices for crop and livestock production to weather modification and a controlled growing environment.

While much of the emerging technology may simply maintain the present productivity trend, four prospective developments have been identified as the type which could help boost agricultural productivity before the year 2000. These potential developments are: (1) improving the process by which plants form carbohydrates through photosynthesis, (2) applying natural and synthetic compounds known as bioregulators to hasten ripening and facilitate mechanical harvesting of some fruits and vegetables, (3) genetic changes that will enable non-legume crops to extract from the air part of their nitrogen requirements, and (4) multiple births in beef cattle. If these new practices come on stream as expected, the additional gain in productivity by the year 2000 could be almost 10 percentage points above the preliminary levels projected by Lu and Quance, which would mean savings of several billion dollars to farmers and consumers.[10]

9 "Agricultural Production Efficiency," National Academy of Sciences, Board on Agriculture and Renewable Resources, Washington, D.C., 1975.

10 Lu and Quance, pp. 45-46.

Policy Considerations

Although higher productivity levels are beneficial to society, these gains are seldom achieved without cost. As noted, many of the improvements in agriculture have evolved from publicly supported research and extension programs. Also, because the demand for farm products is inelastic, gains in output frequently cause prices to decline enough to reduce total revenue in the farming sector.

Why would farmers adopt new technology if total revenue is likely to decline? The answer to this question requires considering the microeconomic effects of a technological change separately from the macro effects. As individuals, farmers are constantly looking for new ways to improve their operations and reduce costs. When new technology is introduced, the innovative farmer who adopts it first frequently realizes substantial savings in cost. Consequently, his profits go up, which is the incentive that the farmer needs to expand the farm operation. However, as additional farmers begin to adopt the new methods and expand their operations, total output in the farming sector will rise, causing market prices to fall. If demand for the commodity is inelastic, total revenue at the new market equilibrium will be lower than it was before the new technology was introduced. The net effect from this adjustment process is that the innovative farmers are able to grow and realize higher incomes by adopting the new techniques. But the farmer who is slow to adopt the new method, or does not adopt it at all, loses out on the opportunity to increase his income. Eventually many of these farmers are forced out of business, representing another cost to society unless they find new employment quickly.

The technological revolution — which has greatly improved productivity — has also dramatically changed the structure of agriculture. From a peak of 6.8 million in the late 1930s, 'the number of farms has dwindled to fewer than 3 million today. While average farm size has risen sharply, the disparity between small and large farms has actually widened over the years, as evidenced by the trend toward a relatively small but increasing number of large farms producing a growing proportion of total output. In 1977, for example, farms with annual sales of $100,000 or more — representing 6 per cent of all farms— were responsible for producing almost 50 per cent of total output. In 1960, fewer than 1 per cent of the farms in the United States had sales exceeding $100,000 per year, and their share of total output was about 17 per cent.

The future structure of agriculture may strongly influence the rate at which new technology is adopted. Research findings suggest that the degree of innovation in a farming operation is often related to farm size.[11] At the smallest farms, innovation is virtually impossible because the risk of failure threatens their survival, and the reward for successful innovation may be small. At somewhat larger scales of operation, however, new technology tends to be adopted more quickly because the risk of failure is smaller. Over the years, medium-scale, family-sized farms have been responsible for the rapid diffusion of technological change in agriculture. On the other hand, the very large, industrial-sized farms tend to resist change. Because of their huge capital investments and the contractual arrangements that many of them have with other business institutions, large farms cannot always adopt new methods and techniques very quickly. In time, though, changes will be made if the economic incentives are strong enough.

Thus, the future prospects for agricultural productivity seem to hinge partly on the structure of farming. If, indeed, family farms are more efficient in promoting and adopting technological change, the recent trends toward large-scale farming may need to be reversed. Hence, perhaps government policies for agriculture should be redirected toward supporting a mix of farm sues that will permit the rapid adoption of cost-saving technology.

While farm structure may be an important factor for future productivity growth, concerns about the availability of energy and the attendant costs are looming ever larger on the horizon. From 1920 to the early 1970s, declining real' prices for energy shaped the mix of resources used in agriculture, as well as much of the growth in productivity. If energy prices in real terms continue to escalate, major research emphasis and funding may shift from agricultural technologies to the development of energy-saving technologies. As a result, agricultural productivity growth could be relatively slow for the rest of the century. Should export demand remain strong as well, competition for U.S. foodstuffs could intensify between domestic and foreign consumers. Thus, it may not be possible to rely on productivity growth in U.S. agriculture to dampen the inflationary effects on food prices.[12] On the contrary, substantially higher food prices, in real terms, may be on the horizon. If this scenario develops, the nation may not avoid substantial resource transfers from the nonagricultural to the agricultural sectors. Indeed, Vernon Ruttan has suggested that the U.S. economy may be past the time when transfers of resources from agriculture to the rest of the economy — through either the

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11 Philip M. Raup, "Some Questions of Value and Scale in American Agriculture," *American Journal of Agricultural Economics.* Vol. 60, May 1978, pp. 305-6.

12 Edward G. Schuh, "The New Macroeconomics of Agriculture," *American Journal of Agricultural Economics,* Vol. 8, 1976, pp. 802-11.

labor or product markets — an significantly enhance national productivity growth.[13] Thus, the last two decades of this century may bring slower productivity growth rates for the non-agricultural sector of the economy, as well as for the agricultural sector.

CONCLUSION

The gains in agricultural productivity have been a phenomenal success story in American economic history. Unfortunately, productivity growth has slowed in recent years. Moreover, the gains in productivity are not likely to increase, and may even decrease, during the balance of this century, particularly if public expenditures for research and extension continue to lag in real terms. In the years ahead, it is unlikely that agricultural productivity will much exceed the recent gains of 1 to 1.5 per cent per year.

The future growth path for agricultural productivity may be bumpy. Unexpected shocks such as an energy embargo or a prolonged drought could cause sharp downward deviations from the trend line. Or an unexpected technological breakthrough of significant proportions could cause a major upward shift in productivity. On balance, though, productivity gains in agriculture are not likely to return to the high levels achieved from the late 1940s through the early 1970s.

Public policies can have a strong influence on the future structure of agriculture and thus on the growth of agricultural productivity. If the adoption of new technology and future productivity gains are related to farm size, policymakers will need to give careful attention to the manner in which new farm program benefits are distributed. Presently, most of the benefits flow to the larger farmers, which explains in large part the growing importance of big farms in the United States. It may be that medium-sized farms, rather than the very small or the very large farms, provide the most fertile ground for rapid adoption of technology.

The nation's response to higher-cost energy may result in a reordering of research priorities, especially in public institutions. To the extent that this occurs, productivity gains in agriculture will likely suffer. If domestic and export demand for foodstuffs continues to grow, higher real food prices can be expected. For the rest of this century, it may be unrealistic to assume that events in the agricultural sector will dampen U.S. price inflation.

[13] Vernon W. Ruttan, "Inflation and Productivity," a paper presented at the annual meeting of the American Agricultural Economics Association, Pullman, Washington, August 1, 1979.