Chapter 3

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Effects of Technological Research and Education

THIS topic is under the general heading of "The Basis of the Cost-Price Squeeze in Commercial Agriculture." The program, therefore, appears to take for granted that research and education are at least partly responsible for some of the present farm income difficulties.

This is not the first time that the finger of suspicion has pointed to research and education. The charge has been made rather frequently in the last two or three years. When it arises in discussion by laymen, the reasoning is about as follows: Most production research and education is output-increasing. We do not need any more farm output to add to our surplus problems. Why not, therefore, slow down, or even place a moratorium on, production research and education for the time being?

Usually, discussions by laymen do not cast suspicion on utilization and marketing research. Studies along these lines are designed to develop larger markets for our surplus products, or at least to give the producer a larger share of the consumer's dollar. The suspicious characters are production research and education which stimulates adoption of the results.

In this program also, the question is limited to technological research and education, and presumably confined to the farm-production aspects of the problem.

Economists recognize that improvements in farm technology are frequently (though not always) associated with direct increases in output of farm products; also that unless demand expands enough to absorb the larger output, the resulting lower prices may actually reduce farm incomes. This is the basis for the charge against technological research and education. We shall examine a little later the special circumstances under which the charge is justified, but before doing this it may be well to mention some other public programs that also increase output. New reclamation projects, conservation and watershed programs, and even credit and price-support programs also have production-increasing effects. All of these programs, including research and education, involve public investments that are intended to benefit agriculture. All need to be examined realistically in order to determine to what extent they temporarily aggravate the surplus problem, and how they might be modified to serve farmers more effectively in the years ahead.

Our assignment is limited to the effects of technological research and education. Frequently, their effects cannot be separated from other production-increasing activities, but insofar as they can be separated, the following questions would seem to be pertinent: Do they increase or decrease net farm income? How are the gains from technological improvement distributed? If the gains tend to be shifted away from farmers to the benefit of other groups, is there a conflict between progress and income improvement and stability in commercial agriculture? If so, can the conflict be reconciled?

To deal with these questions, it seems necessary to review briefly the objectives of technological research and education, and to trace the impacts of adoption of improvements with respect to:

1. Effects on output.
2. Short-run effects on costs, and on gross and net incomes of individual farmers.
   a. On initial adoption.
   b. When adoption becomes general.
3. Short-run effects on farmers as a group.
4. Short-run effects on other groups.
5. Long-run effects on farmers and other groups.

OBJECTIVES OF TECHNOLOGICAL RESEARCH AND EDUCATION

The objectives of technological research and education frequently are stated in the general terms of increasing the efficiency of agriculture. If more specific objectives are outlined, they usually illustrate how farmers would benefit if, for example, the yield of a crop is increased, or if the costs of producing it are reduced. Little attention has been given to how the benefits from increased efficiency are likely to be distributed, although the benefits to the general economy have been recognized. An individual worker in research or extension may put his objective simply as "helping farmers to make more money." The assumption here is that if individual farmers make more money, farmers as a group will profit also, and society as a whole will benefit. Unfortunately, the process is more complex than this, but as most of our research and education has proceeded on these assumptions, we need to examine the effects on this basis.

Technological research is conducted by public agencies, endowed institutions, and private firms. Public agencies and endowed institutions are primarily interested in advancement of knowledge and enhancement of farm and general welfare. Private firms are justifiably interested in developments that will be profitable to the firm, but they recognize that the improvements offered must also be profitable to the farmers who use them. The research under consideration may be applicable only to farm production as, for example, fertilizer, or it may be applicable to the economy generally, as are automobiles and motor trucks.

Whenever new production techniques are developed that decrease the

total inputs of resources per unit of farm output, adoption of the new techniques is advantageous to individual farmers.[1] Educational activities are organized to disseminate to farmers the advantages of adopting new techniques of this kind. Sometimes the process of adoption involves development of the necessary technical and managerial skills that are needed for successful use of the new techniques. In fact, farmer "know how" is frequently the key element in profitable adoption. We should recognize also that the foundation for requisite knowledge is the increasingly higher level of basic education of farm people.

The primary appeal that education makes for adoption of improvements is the possibility of increased income to the individuals who adopt them. Or, in some instances, the appeal may be in terms of reducing the workload of the farm family. Advantages of improvements are made known to farmers through the various educational activities, and in that way adoption is accelerated.

Some of the farm programs supplement educational activities by providing direct financial and other inducements for adoption of improvements.

EFFECTS ON OUTPUT

Historically, substitution of mechanical power for animal power has been the most important output-increasing improvement in agriculture. Release for other uses of cropland that formerly produced feed for horses and mules on farms was responsible for about half the increase in output in the interwar years, and it has accounted for about one-fourth of the increase since the beginning of World War II. Since 1920, this land-saving improvement has released some 70 million acres, or about one-fifth of our harvested cropland, for production of marketable products.[2] Its future influence will be relatively small because less than 10 million acres are now used to produce feed for horses and mules.

Improvements in crops usually increase the yield per acre, and livestock improvements result in larger output per animal. In one sense, however, the large segment of research devoted to protection against pests and diseases of both crops and livestock is an exception. A large part of the current research program is needed merely to maintain the current level of production without contributing to an increase in output. Output likely would be greatly reduced if research in these fields were to be discontinued.

Similarly, protection research is needed to maintain our soil and water resources, although frequently maintenance is inseparably combined with improvement that results in larger output.

Machines that save either labor or capital usually have no direct

[1] Assuming no change in factor prices, and that the necessary capital can be obtained.

[2] Substitution of mechanical for animal power also has been a major labor-saving innovation, and this has added to the problem of resource adjustment.

effect on output. An example of exceptions to the general rule would be a machine for more effective placement of fertilizer. In this instance crop yields might be increased even with some reduction in fertilizer use per acre. Also, if a new machine is labor-saving, it may release sufficient labor to permit increased output of the product on which it is used, or to expand the output of some other product. Similarly, if the purchase price of a machine is reduced because of technological improvements, the capital saved might be invested to increase output – for example, in the purchase of more fertilizer.

Although there are some exceptions, the conclusion appears to be well founded that most technological improvements do increase output. As previously noted, adoption of new technology increases output per unit of resources. The net effect on total output depends, among other things, on whether aggregate resource inputs are reduced. Figure 3.1 shows the trend of farm output in relation to the trend in population. The relatively faster rate of growth in farm output during the postwar years largely explains the unbalance between total farm output and available markets. It does not explain the unbalance in specific products, such as wheat and cotton. But if total farm output had not increased by 11 percent since 1951, or if it had increased by only half as much, price-cost relationships would now be much more favorable.

Undoubtedly, technological research and education have prepared the way for the increases in output that have occurred in recent years, as well as for the earlier increases that made it possible to provide

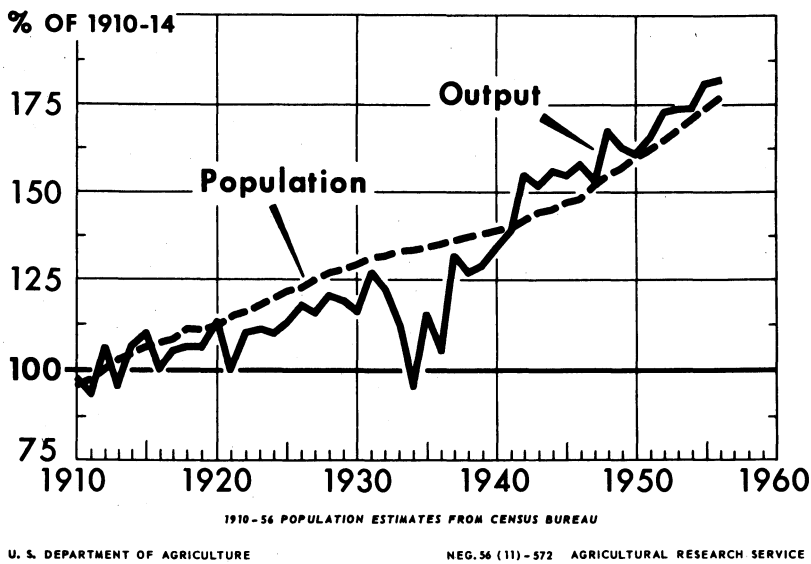

Fig. 3.1 - United States population and farm output.

"food enough" for ourselves and our friends abroad during the late war and its aftermath of rehabilitation. Neither technical advances nor the development of technical and managerial skills that made possible their adoption occurs spontaneously. They are largely the product of research and education. But the credit for the increased production during the war and its aftermath, as well as the responsibility for more rapid expansion of output than of markets in recent years, must be shared with the other production-increasing activities previously mentioned.

We shall not attempt in this paper to assess the relative importance of the different output-increasing activities. Much of the following discussion, therefore, relates to the effects of output-increasing forces from whatever source, recognizing that the initial impetus for much of the expansion is found in research and education. We shall discuss first the short-run effects, which may cover a period of several years, and then take up the longer run consequences to farmers and the general economy.

SHORT-RUN EFFECTS ON COSTS, AND ON GROSS AND NET INCOMES OF INDIVIDUAL FARMERS

It is generally recognized that the market demand for most farm products is so inelastic that a smaller total output of, say, wheat or potatoes, sells at prices enough higher to bring a higher gross value than would a larger output. Therefore, a cost-reducing improvement that increases production eventually may mean much lower prices for the product and a lower gross income to individual farmers, unless demand increases fast enough to absorb the additional output.

But individual farmers balance the advantage of adoption in relation to product prices without considering the potential price effects of larger supplies. And farmers who first adopt a cost-reducing and production-increasing improvement benefit from the resulting direct gain until or unless the price of the product is affected. Therefore, those farmers who first adopt a well tested improvement gain in the early period of its adoption. This is a powerful incentive for adoption by those in a financial position to make the change. In the case of price supported products, farmers continue to gain unless allotments and price supports are reduced as more surpluses accumulate.

We should also recognize that farmers who cannot, or who for some other reason do not, adopt the new techniques are not injured because other farmers adopt them until or unless the price of the product is reduced. However, the difference in net incomes will increase between those who adopt the improvement and those who lag in adoption.

What happens then, when a production-increasing improvement is widely adopted? If market demand is expanding rapidly, as it did during the war and rehabilitation years, the larger output is absorbed without a decline in prices. If the market expands at least as rapidly as the increase in output, individual farmers will retain the direct benefits, but

other groups will benefit also because the larger output will become available at lower prices than would otherwise prevail.

Under less favorable conditions, demand may expand less rapidly than output, as in recent years, or it may fail to expand and perhaps may actually diminish. Prices are then likely to go down. How individual farmers fare under these conditions will depend on: (1) the extent of the decline in prices, (2) the cost structure which farmers have developed, and (3) their ability to adjust to the new situation.

Frequently, adoption of a production-increasing improvement involves a large fixed investment for equipment — supplemental irrigation, for example. Once such an investment has been made, it becomes for a number of years a fixed, or at least semifixed, input that has increased the total cost of operation despite significant reductions in cost per unit. Even variable costs such as fertilizer add to the total cost at the same time that cost per unit is decreased.

The added costs of producing the larger output may, therefore, result in a lower net return to the farmer when price declines result from a larger volume of marketable products. If the price goes down so much that the larger output brings no more gross income than before the improvement was adopted, individual farmers can continue to gain only if their total costs have been reduced in the adoption process. Although it is difficult to achieve a lower total cost for a larger output than was previously incurred for a smaller total output, it can be done under certain conditions. Usually it involves a reorganization of the entire farming system and a considerable saving of hired labor.

If a farmer's costs are higher than they were before he adopted the improvement, and his gross income has been reduced by declining prices, his annual loss may be greater than his annual gain during the first few years of adoption. But the road back to the previous position has been closed for a number of years. His investments for adopting the new practices have become a part of his fixed costs. Even if the new practice involves only variable costs such as fertilizer, he is likely to find that his net return would be lower if he lessened its use. As an individual operator, he cannot gain by reducing production.

SHORT-RUN EFFECTS ON FARMERS AS A GROUP

As indicated previously, all farmers who adopt an improvement retain the direct gains from adoption if the market demand is expanding fast enough to absorb the increase in output without a decline in prices. And as prices do not fall, the nonadopters are not injured. It can be argued that, with inelastic demand, prices would rise in response to a smaller supply under such conditions. Therefore, farmers would gain even more if production did not increase. But this condition would be purely temporary because other ways would be found to increase output, but at higher costs. Farmers would be even more vulnerable in the event of slackening demands. Therefore, the crucial question is how

farmers as a group fare under a price decline resulting from a production-increasing improvement.

We have already traced the impact of a price decline on individual farmers and noted that they may lose part or all of the original gain from adoption of an improvement. In fact, their net incomes may be lower than before adoption. Under these conditions, the nonadopters would experience relatively greater income losses because they would have no increase in output to help offset the decline in price.

We conclude that, in the short run, price declines because of increases in output may result in annual losses to farmers as a group of part, all, or more than the original annual gain from adoption of an improvement. How long the annual losses will continue will depend upon how rapidly farmers can adjust to the new situation, as well as on whether market demand is expanding for the products affected.

Under the assumptions of perfect competition and free mobility of factors, enough resources should be shifted out of unprofitable enterprises to make production profitable again for those who have sufficient competitive advantage to remain in production. But whether such shifts actually will be made in the short run will depend upon the availability of better income alternatives to farm people who are caught in the squeeze; also upon whether they are in position to take advantage of other opportunities. A wheat producer with an $80,000 investment in land and equipment may not be able to liquidate without the loss of most of his capital. Consequently, he decides to weather the storm. Some producers who are heavily in debt may be forced to liquidate, but the land will move into financially stronger hands and remain in production. Such a shift, however, may result in higher incomes to the fewer workers who remain on farms. In farming areas where several enterprises are closely competitive, it may be possible to shift, say, from beef to dairy, or to cash crops. But when prices are relatively low in all lines, the only alternative is nonfarm employment, and even that may not be available at all times.

Adjustment to a surplus situation, whatever its origin, is likely to be both painful and slow. Moreover, the impediments to adjustment may be sufficiently strong to offset the forces that pull in the direction of adjustment. Consequently, a chronic condition will develop unless the impediments are removed. Our recent experience appears to verify these conclusions. Price, cost, and income relationships have been relatively unfavorable in most farming areas since 1951. Still, total farm output has moved upward by about 11 percent in five years. We had the same experience from 1922 to 1929, although output increased more slowly at that time — about 9 percent in seven years.

Why do farmers as a group increase output in the face of low net incomes? At present, our explanation consists of hypotheses that need quantitative verification. Perhaps the momentum gained in responding to earlier favorable price-cost relationships is a partial explanation. It is difficult for farmers to realize that market conditions have changed, and easier for them to assume that the price decline is temporary. In

the more recent period, some of the investment for increased capacity made up to 1951 became available for increasing output after the price had dropped, and the pressure on farmers to utilize fixed resources needs no further elaboration. Also, some farmers find it profitable to adopt new production-increasing techniques even under relatively unfavorable conditions. Actually, however, farmers have been decreasing their rate of net investment in machinery since the peak year 1948. (See Fig. 3.2.) Purchases of new machinery in 1956 were at the lowest level since 1947. But machinery inventories are still quite adequate, and even further increases in output are not likely to be retarded by shortages of machinery.

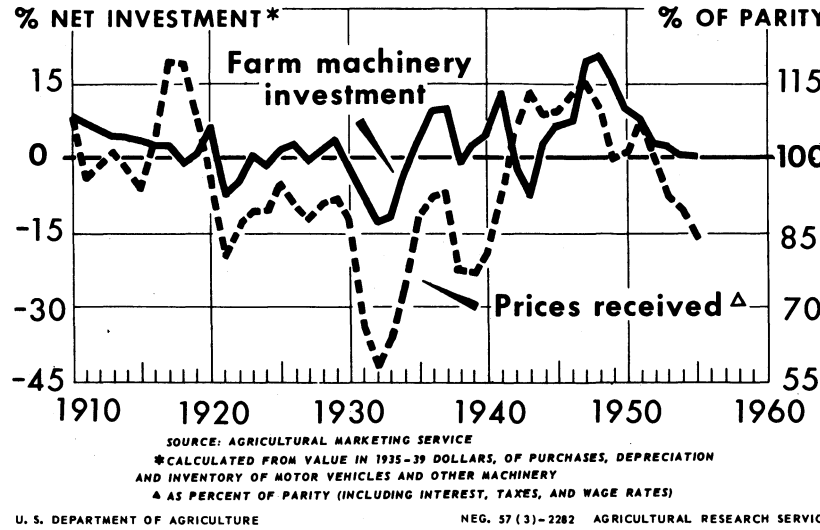

Fig. 3.2 - Farm machinery investment and farmers' prices in the United States.

From 1951 to 1955, farmers continued to increase their outlay for some of the variable cost items such as fertilizer, pesticides, and some of the processed feeds. Apparently, even at the lower prices for farm products, the return above these variable costs was sufficient to increase their use in combination with fixed inputs. Figure 3.3 reveals, however, that the rate of increase in the use of fertilizer has declined since 1950, and preliminary data indicate that the total quantity used in 1956 actually dropped slightly below the level of the previous year.

Acreage allotments and marketing quotas have been in effect for some crops during at least a part of this period. Although they have reduced production of cotton, wheat, rice, tobacco, and peanuts, other crops

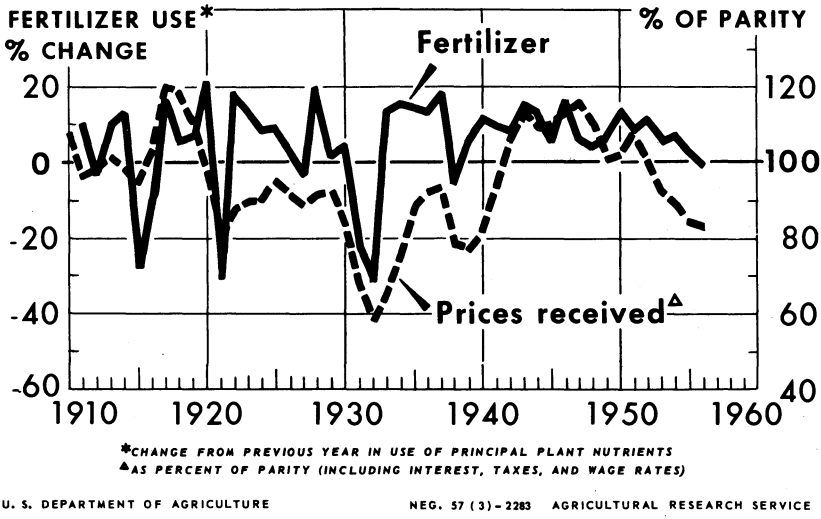

Fig. 3.3 - Fertilizer use and farmers' prices in the United States.

have been grown on most of the diverted acreage.[3] Also acreage restriction of price-supported crops induces greater use of fertilizer and other inputs on the limited acreage. Consequently, with higher production on the allotted acreage and substitute crops on the diverted acres, the net result in some instances may be an actual increase in total output.

Irrigation development resulting from both public and private investment has contributed to increased output. Conservation activities also have tended to increase output.

These developments have all resulted in higher production per acre. The rise in livestock production per breeding unit since 1950 has been even greater than the increase in production per acre. (See Fig. 3.4.) This is partly the result of a larger feed supply and, hence, is directly related to crop production. But it also stems from direct improvement in the livestock enterprises, especially in production of broilers, eggs, and milk. For example, a large number of the higher-producing cows resulting from artificial insemination have come into production in recent years. Antibiotics, and other feed additives, and disease control also have had significant effects.

If these tentative explanations are accepted for some of the output increases of recent years, what about the 1920's? There were no farm programs to give an upward push at that time. But the tractor, truck, and combine harvester had been developed to such a point that adoption

[3] "Effects of acreage-allotment programs 1954 and 1955: A summary report," Prod. Res. Rept. No. 3, ARS, USDA, June, 1956.

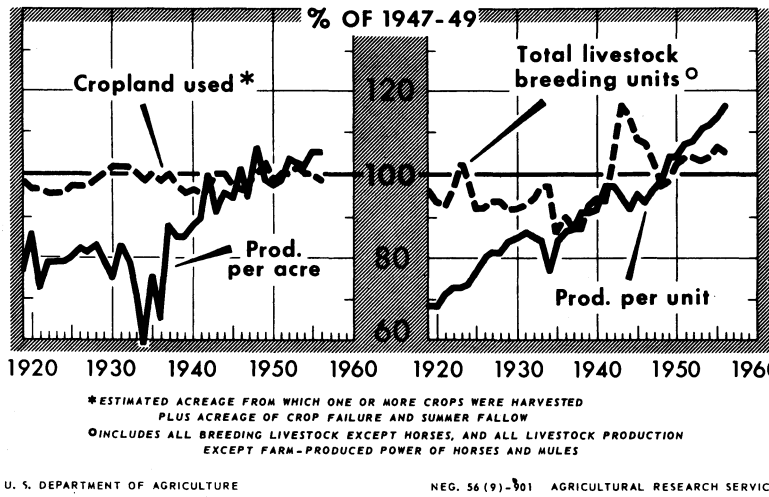

Fig. 3.4 - Farm production per acre and per animal in the United States.

constituted significant economies. Credit was available for purchase of these new machines. The equipment had a special advantage in the wheat areas, with the result that millions of acres of sod were broken in the Great Plains and the Pacific Northwest. Livestock production also increased during these years, as farmers were struggling to find more intensive enterprises to meet the fixed charges on high indebtedness incurred during the war boom. In one respect, the 1920's were more favorable to output expansion than the 1950's. Prices paid by farmers were much below 1920 levels, although they did not decline as much as prices received. Net farm incomes made some recovery in the 1920's.

Does the recent decrease in the rate of purchase of new machinery, and even in use of fertilizer, foreshadow a slowing down in output? Is this slowing down in farm expenditures and capital investment the result of financial exhaustion of many farmers and, therefore, a withdrawal of capital resources from production? Availability of nonfarm employment in recent years has continuously reduced the labor force on farms. About 9 percent fewer man-hours were used in 1956 than in 1951. But enough capital and current inputs have been substituted for labor to maintain total inputs and to achieve the increases in output. (See Fig. 3.5.) Assuming average weather, output will not be decreased unless there is an actual withdrawal of land, labor, or capital resources. The acreage reserve part of the Soil Bank will result in a temporary withdrawal of land resources, but a part of this effect could be offset rather soon by soil improvement and summer fallow on reserve acres, and by applying relatively more labor and capital to the land remaining in use.

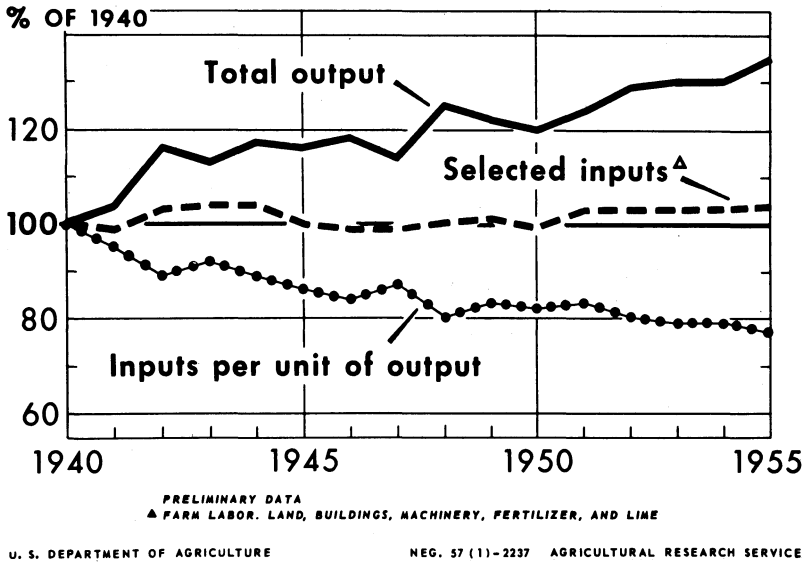

Fig. 3.5 - Farm inputs per unit of output.

SHORT-RUN EFFECTS ON OTHER GROUPS

When market demand increases, the general economy benefits from production-increasing improvements because the larger output tends to prevent a rise in prices. Under these conditions the benefits of improvement are shared by farmers and other groups. Farmers retain the direct gains, but other groups benefit from a larger output available at relatively lower prices. This was the case during the war and the early postwar years. But we have already seen that when production increases faster than demand for the product, the decline in prices will shift part or all of the original gain, or even more, away from farmers to other groups.

How much of the gain is passed on to consumers and how much is retained in processing and marketing channels depends on the organization of the processing and marketing channels and on the relative bargaining power of the groups engaged in these activities. In recent years, a considerable part of the gain has been absorbed by additional processing and marketing services, higher wages to workers in these fields, and increased profits in some lines.

It seems evident that other groups in the economy benefit from production-increasing improvements in agriculture under most circumstances. In periods of relatively low business activity, however, a labor-saving improvement that releases workers from agriculture may aggravate unemployment. Consequently, for the nation as a whole, the gains could be offset temporarily by the cost of unemployment relief.

LONG-RUN EFFECTS ON FARMERS AND OTHER GROUPS

In the longer run, technological research and education have contributed immensely to public welfare. The new technology has made possible increased production of food and fiber with much less labor and other resources. For example, with the farming practices in use as late as 1910, one farm worker could provide food and fiber enough for only 7 persons. In 1956 one farm worker provided enough for 20 persons. Over the years the farm labor released as a result of technological improvement has become available for development of other industries and services in our economy.[4] In this way, technological advances in farm production have contributed immeasurably to the technical and economic progress that has meant a high and still rising level of living in this country. Furthermore, in a growing economy greater farm output will be needed in the years ahead. For example, an increase in output of about one-fourth from 1956 to 1975 may be needed to meet projected market demands. However, most of the increase in demand will come in later years.

How do farm people share in the long-run benefits of improved technology? As consumers they share in the general economic progress. Perhaps the best test of their gains as producers is the trend of real incomes for farm workers. (See Fig. 3.6.) But other contributions to

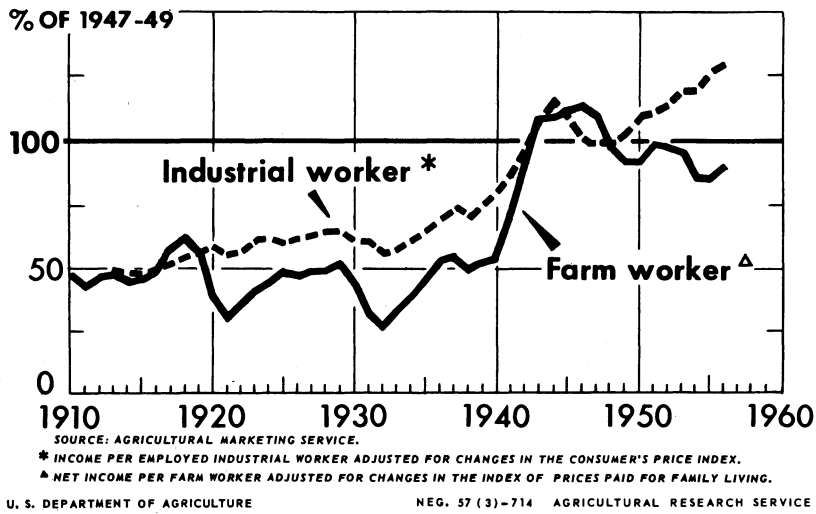

Fig. 3.6 - Real income of farm and industrial workers.

[4]Some of the released labor is now engaged in producing goods and services formerly produced on the farm.

farm living also need to be considered. Electricity and other improvements have greatly relieved the burden of physical labor both on the farm and in the farm home. Community facilities now provide better education and health services. Improved roads and automobiles have brought local towns or even larger trading centers within a few minutes' ride. Rapid transportation, radio, and television also have increased urban contacts, and most farm people are now a part of the same cultural group as their urban cousins.

Better education and closer contacts with urban groups have greatly increased the mobility of human resources in agriculture. Farm people are now much better informed about income opportunities in nonfarm occupations. Good roads and automobiles have made it possible to combine rural living and nonfarm work and to explore work opportunities in other areas. Historically, adjustments in agriculture have been made more easily in the areas adjacent to urban development where other employment was available.

What would be the income and living conditions of farm people today if little or no technological improvement had taken place on farms since the beginning of World War I? The conditions that would have developed in this country with a combination of industrial progress and a static agriculture are almost impossible to visualize. Farm people isolated from urban developments probably would have become a peasant society. In other countries where those conditions have prevailed, we find either small peasant farms, or large farms operated with low-paid labor, or both types of situations. Undoubtedly, farm prices would have risen with the increase in market demands.[5] Increases in output then would have been obtained by devoting more of our land resources to crops and by applying more labor and capital to our productive lands. Land values probably would have absorbed most of the gains. In other words, the secular law of diminishing returns would have operated about as postulated by the classical economists. At any rate, it would be difficult to contend that farm people would have had a higher and more satisfactory level of living in the years since 1910.

Figure 3.6 indicates the broad sweep of changes in real income per worker of farm and factory workers since 1910. Perhaps a more effective and somewhat more valid comparison can be made by considering percentage changes in real income between periods of relatively low industrial unemployment. These comparisons are made in Table 3.1.

Real income per farm worker nearly doubled from the years 1910-14 to 1953-55. However, the real income per employed factory worker increased about one and a half times over the same period. In other words, although farm people have benefited greatly in an absolute sense, their rate of gain in real income has lagged considerably behind the gain achieved by factory workers. From the years 1947-49 to 1953-55, real

[5]More people would have remained in farming, and they would have increased production under existing technology. The cost structure, including land costs, probably would have been even higher; and commercial farmers with high fixed charges for debt service would have been in a vulnerable position in a period of slackening demands and declining prices.

Table 3.1. Comparisons of Real Income Change Between Farm and Factory Workers

Period	Percent change in real income per worker	
	Farm	Factory
1910-14 to 1925-29	8	29[a]
1918-20 to 1942-44	98	92
1910-14 to 1953-55	96	149[a]
1925-29 to 1953-55	81	92
1947-49 to 1953-55	-11[b]	21

[a]Based on a 1913-14 average for the beginning years.
[b]No adjustment is made for the higher equity investment per worker in 1953-55.

income per employed factory worker increased by 21 percent. The unfavorable income situation of recent years tends to obscure the long-term benefits. We must bear in mind, however, that technological developments are not responsible for all of the income changes — either favorable or unfavorable. And we must also recognize that short-run unfavorable developments, from whatever source, greatly retard the benefits of progress over the longer term, and may wipe them out entirely for many farm people.

CAN CONFLICTS BETWEEN PROGRESS AND INCOME IMPROVEMENT AND STABILITY BE RECONCILED?

It is evident that although farmers have benefited greatly from production-increasing improvements, the impacts of these improvements can also contribute to instability of income for farm people over the short run. But the solution to this problem does not lie in retardation of progress by restricting research on technological improvement. It must be found in removing the obstacles to adjustment that are the root causes of instability and in working out ameliorative measures to help those who encounter substantial hardship from major changes. Agriculture must go forward with the rest of the economy. We can no longer consider farm people as a group apart. Both technical and economic progress is necessary if agriculture is to provide income opportunities that will attract and retain persons of ability. Industrial progress and a static agriculture are incongruous under present conditions.

The real conflict between progress and income improvement and stability arises from assuming that adjustments to important technological developments, or to any other production-increasing forces, can be made automatically. For example, about half of the increase in output during the interwar years arose from substitution of mechanical power for animal power. One solution to this problem would have been to slow down or actually prevent this shift. Although it seems strange now, there were strong advocates of this solution at that time. The opposite

solution would have been to adopt measures to facilitate adjustment to the new situation.

When surpluses and low prices became really serious because they were accentuated by deep depression, programs intended to relieve the surplus problem were developed. They were developed as emergency programs, however, and they did not have an adequate research foundation. The adjustment programs in effect today are based largely on those developed during the 1930's, and the research basis is still inadequate.

The question then arises as to what research can contribute toward facilitating adjustments to production-increasing improvements, or to other significant changes, and providing a better foundation for ameliorative programs. We believe that research can be organized in a way that will greatly facilitate adjustments to changing conditions. It can contribute along the following lines:

1. There are some opportunities for expanding markets beyond their normal rate of growth. For example, the development of the broiler industry probably expanded the total market for meat. In this way, it has caused a shifting of consumption from lower value to higher value products, and provided an opportunity for employment of more resources in agriculture.

2. It may be possible to develop new crops that will increase total market outlets. Earlier development of soybeans undoubtedly expanded the total market for farm products. There is some discussion now that entirely new uses can be found for castor beans. If these new uses can be found, the market for farm-produced oils will be expanded even more. But exploitation of this potential market depends on the development of economical methods of production, including an effective mechanical harvester.

3. Although many difficulties must be resolved in expanding export markets, research may reveal new foreign outlets that will result in increasing the market for farm products.

4. Research in the economics of production can greatly facilitate shifts toward the products with the greatest potential market expansion, including those indicated under points 1, 2, and 3. Such research will be needed especially if new crops or new uses are developed. But perhaps the most important contribution of research in the economics of production lies in facilitating shifts toward production of livestock products, fruits, and vegetables. The normal market expansion resulting from increases in population and in purchasing power seems likely to favor these products.

5. Research in economics of production needs to give special attention to the obstacles that prevent rapid adjustment to new conditions and ways of overcoming them. Research of this kind will include emphasis on improvement of the situation for those who suffer substantial hardship as a result of changing conditions. The goal should be to find ways of improving incomes for all farm people — hired workers as well as farm operators.

6. At present, farm workers probably would receive higher returns

if fewer production resources were used in agriculture. Economic analysis would suggest a shifting of the least productive resources into other uses. The conservation reserve features of the Soil Bank and the Great Plains conservation programs are directed toward this objective on the land front. Research is needed to make them more effective. For example, to the extent that entire farm units of low productivity can be shifted, both land and labor of relatively low productivity are devoted to more productive uses.

Shifting land of low productivity into grass or trees will build up a reserve of productive capacity that may be needed in an emergency or in the distant future. Other means of lessening present exploitation of land and water resources and conserving them for future needs should be fully explored. It may be possible also to slow down the rate of addition of capital inputs in agriculture, especially those that involve public investments for new development.

One of the goals of farm people that is frequently stated is an opportunity to earn real incomes equal to those available in other occupations with the same effort, skill, and managerial ability. Research is needed to determine the alternative ways of achieving this goal. Will it require better health, education, and other community facilities in rural areas? Will such facilities in turn improve the opportunity for some rural people to go into other occupations that afford a better outlet for their talents?

Here again, encouragement should be given to shifting resources that are now bringing the lowest return; for example, migratory labor and stoop labor of all kinds, provided that better income alternatives are available for these workers. Research to mechanize the operations performed by stoop labor will need to be stepped up to provide economical substitutes for low-paid hired labor.

7. Economists must be alert in detecting emerging changes and in analyzing their potential impacts. They should appraise the structure of agriculture that is likely to result from the pending changes and be in a position to suggest ways of modifying the effects of undesirable changes. For example, the potential effects of the increased tendency toward vertical integration of farm production with furnishing of farm supplies and with processing should be carefully analyzed. More and more projections of longer term prospects are needed, and great emphasis should be given to analyses of their implications concerning the future welfare of agriculture.

We conclude that physical and biological research should continue in all major areas. But greater emphasis should be given to basic research, to protection research as previously noted, and to other types of applied research that give promise of aid in solving adjustment problems; for example, more productive grasses for the Great Plains. However, the greatest need is for a combination of natural science research with greatly expanded research in economics of production. Research to facilitate adjustments to changing conditions is essential if farmers are to share fully in the benefits of technological progress. Finding a solution to the conflict between progress and income improvement and stability is the real challenge to researchers in economics.

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Discussion

SINCE there is little basis for disagreement with the analysis presented by Drs. Johnson and Barton, I shall devote most of my discussion to extending certain of the ideas developed by them. Most of my attention is directed to the long-run considerations.

The long-run distribution of the benefits of technical development (defined as shifting to a higher production function) in agriculture between farmers and non-farmers can assume three different forms:

1. The welfare of both farmers and non-farmers is improved.
2. The welfare of one group, farmers or non-farmers, is improved while the welfare of the other group is not changed.
3. The welfare of nonfarm groups is improved while the welfare of farmers is diminished.

If we ignore intra-group changes in welfare, we can conclude that either of the first two effects would improve the total welfare of society. However, since we are unable to make inter-personal comparisons, we must defer judgment on the third possibility.

In an earlier paper Dr. Johnson[1] states that agricultural economists tend to be pessimistic about the long-run benefits of technical development to farmers. He attributes this pessimism to a failure to appreciate possibilities of lower costs for a larger output through new production combinations. I believe this notion has merit although Dr. Johnson places less emphasis on this possibility in the present paper. Possibilities of lowering costs are perhaps greater in the case of labor-saving, land-using types of innovations.

Current research at Oklahoma A. and M. University indicates that the labor and machinery supply on the modal 320-acre and 640-acre north central Oklahoma wheat farms are the same. Similarly, there appears to be no real difference in the level of practices or the input-output relationships. Furthermore, the present organization and the programmed "optimum" plan is such that the crop acreages and livestock numbers simply double in moving from the one-half section to the one section unit. Thus, in this case, doubling the land input apparently

[1]Johnson, Sherman E., "Technological changes and the future of rural life," Jour. Farm Econ., Vol. 32, No. 2, May, 1950.

doubles the output with no increase in non-real-estate capital and little increase in hired labor.

There are, however, reasons to believe that the results mentioned (i.e., no change in output per acre after resources were recombined) are not applicable to any large number of resource situations. The area studied is one of homogenous soil resources where alternative enterprises and production practices are quite limited. In an area such as the Southeast, output per acre may well increase when units are consolidated due to the employment of more intensive production practices. Thus, perhaps we must tentatively conclude that innovations which lower total costs are the exception rather than the rule even after resources are recombined. In any event, it is significant that although the equipment making possible the savings indicated in the Oklahoma area have been available for many years, few operators have adjusted their resource combinations along the indicated lines. This is evidenced by the fact that the 320-acre unit is the modal farm size in the area.

If, as is generally agreed, technical innovations usually increase total costs, then in the absence of an increase in demand sufficiently great to increase the gross incomes of farmers as much or more than costs, successful technical research and education has a depressing effect on net incomes in agriculture. This follows from the inelastic nature of the demand function for farm products in the aggregate and for most individual products. Therefore, we would conclude that in the long run the major benefits of technical development in agriculture accrue to nonfarm segments of society. These benefits are in the form of resources made available to increase the production of non-subsistence goods and services. As Dr. Johnson indicates, these benefits to society have been tremendous. Yet as significant as technical progress in agriculture has been, we should recognize that certain measures tend to overestimate the resources released by agriculture. For example, some of the jobs formerly performed by farmers have been shifted to organizations serving farmers. Thus, some movement of labor from farms has not resulted in net reduction in labor employed in agricultural production.

The farmer as a member of society shares in long-run benefits of technical development in agriculture. In fact, most of the farmer benefits enumerated by Johnson accrue to farmers as consuming members of society rather than as producers of agricultural commodities. An additional important benefit is that the expanding nonfarm economy, made possible in no small part by technical development in agriculture, offers one means of facilitating the constant resource adjustments, within agriculture and between agriculture and other industries, which are a necessary part of a productive and growing economy. However, since, as the data presented by Johnson shows, farm incomes have not increased as much as those of other groups, farmers as consumers have not been able to share in the increased productivity of the economy to the extent that many nonfarm groups have. Furthermore, farm income data, such as those presented, reflect varying degrees of compensation paid

farmers by society. Thus, such data would appear to underestimate the farm to nonfarm income transfers generated by market forces.

Technical research and education which reduce the risks and uncertainties of farming may increase the welfare of farmers even though they tend to reduce net incomes. Many of the technical developments which reduce risk and uncertainty are output increasing and, therefore, given a fixed demand, income reducing. However, if farmers prefer the lower but more certain income, farmer and society welfare may be increased by such innovations.

The innovating farmer in an area of rapid technological development, producing a commodity with a relatively high price and income elasticity of demand which has enjoyed rapid technological development, is in the most favorable position to make short- and long-run adjustments to technological developments. On the other hand, the farmer who is slow to adopt innovations, who is in an area of slow technological development, and who is producing a commodity for which development has been slow and which has a relatively low price and income elasticity of demand, is most adversely affected by technological development.

The various technological developments in agriculture have probably caused important long-term intra-industry income transfers. Technology has not been developed or adopted at the same rate in the different areas or with respect to different commodities. Such a differential rate of technological development benefits areas or commodities where development is more rapid at the expense of areas or commodities where development has been slower. In like manner, the early adopter benefits at the expense of the late adopter. Thus, even in the absence of inter-industry income transfers, technological development would not, in the long-run, appear to improve the position of one group without injuring other groups.

Intra-agricultural income transfers are most pronounced where there is a differential rate of technological development between competing products or competing areas. For example, the development of corn hybrids probably improved the position of producers in areas where corn yields were substantially increased relative to corn producers in other areas and producers of competing feed grains. In similar fashion newly developed hybrid grain sorghum may allow certain grain sorghum producers to gain at the expense of other feed grain producers.

An output increasing innovation can, of course, in the long-run decrease the incomes of the innovating group as well as competing groups. Whether this occurs depends on the extent to which prices are reduced relative to the per unit cost reduction resulting from the innovation. However, the important point is that even though an innovation increases the net income of farmers as a group, the welfare of farmers may be decreased due to changes in income distribution within agriculture.

Public research and education funds could be allocated so as to minimize income transfers within agriculture. Scientific discoveries or advances are probably not predictable. However, some degree of correlation would be expected between the funds and effort expended in a given

area and the progress made in that area. Thus, major public research and education funds could be directed to depressed areas or commodities in an effort to equate, to some extent, the rate of technical development in agriculture. Such an allocation would not, however, maximize overall social progress from a given research input.[2]

The fact that research and education are not the sole factors responsible for shifting the agricultural supply function and that not all technological research and education are publicly sponsored are important points. The first point suggests that a given reduction in the rate of supply increase may be achieved, with less sacrifice of economic progress, by policies influencing non-research and education factors than by rationing, in some fashion, resources devoted to research and education. The fact that private firms are important elements in agricultural research and education implies that the rate of technical advance is not a variable that can be fully controlled by public policy. In fact, in a full employment economy, expansion of private agricultural research and education activities would be expected if publicly supported research were curtailed. In addition, only publicly supported research and education can be planned to guide progress in an optimum direction.

Dr. Johnson has outlined a challenging and extensive program of research designed to shed light on problems of resource and market adjustments in a growing economy. Over the past 50 years farm management workers in this country have made tremendous contributions to the efficiency of a growing commercial agriculture. During the next 50 years we must not only continue analyses of farm firms, but we must expand our efforts and direct more attention to analyses of factor markets and of the structural nature of dynamic supply functions. Farmers and society expect workers in farm management-production economics to provide a research basis for a rigorous and forward-looking evaluation of alternative resource-market adjustments. The interest evidenced in this conference certainly suggests that our profession will not betray this trust.

[2]Heady, Earl O., "Basic economic and welfare aspects of farm technological advance," Jour. Farm Econ., Vol. 31, No. 2, May, 1944.