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Economic Return to Public Investment in Agricultural Research and Extension

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ECONOMIC RETURN TO PUBLIC INVESTMENT IN AGRICULTURAL RESEARCH AND EXTENSION

*Willis L. Peterson

In 1975 U.S. taxpayers will be called upon to pay in excess of one billion dollars for the support of agricultural research and extension conducted by the U.S. Department of Agriculture and the various state agricultural experiment stations. Although one billion dollars is a lot of money at least in total, it averages out to about $15 per family for the year. But the relatively modest per family cost should not prevent us from asking, is this expenditure worthwhile?

My task this morning is three-fold: first I will attempt to explain how we evaluate the benefits of agricultural research and extension. Second I will present some measures of the economic return to this investment, and lastly I'll offer some observations and suggestions which I think will bear upon the productivity of agricultural research over the next 100 years.

I Research and Productivity Growth

It is helpful to view agricultural research as a production activity having both inputs and an output. The principle inputs consist of scientific man-years, laboratory facilities, test plots, libraries, computers, etc. The output of this production activity consists of new

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knowledge. This knowledge comes in many forms and is utilized in several ways. In its most basic form it may further our understanding of nature and allow us to make additional scientific advances that would otherwise be impossible. For example without knowledge of genetics, cell biology, and plant and animal physiology little progress could have been made in the areas of plant and animal breeding and nutrition. Other knowledge comes in more applied forms such as new higher yielding varieties of crops, or it may come in forms that can be directly utilized by farmers such as knowledge about nutrient requirements of livestock or about cultural practices that increase crop yields. Some of the knowledge is utilized by the farm supply industry (firms producing and supplying inputs to agriculture) and results in the production of new, more productive inputs for agriculture, such as the host of new chemical inputs that help control weeds, insects, and diseases. In general we can say that agricultural research produces new knowledge which in turn makes possible new, more productive inputs for agriculture and increases the productive capabilities of farm people.

Knowledge produced by agricultural research is a capital good and has much in common with more traditional forms of capital such as buildings and machines. For one thing it pays off over a long period of time. For example, current generations are still benefiting from the early advances in genetics and plant physiology.

But knowledge also is subject to depreciation and requires annual maintenance just to remain intact. Scientists grow old and pass from the scene. Their knowledge must be passed on to new generations. Much of the training in colleges and universities is aimed at this end. Knowledge embodied in new inputs also becomes obsolete. Disease resistent varieties of crops succumb to new organisms, or still newer and better inputs come on the scene that make the old ones obsolete, e.g. the modern combine replaced the old threshing machine which at one time was a new, more productive input itself.

Thus a sizable fraction of the current one billion dollars plus annual expenditure on agricultural research is for maintenance purposes. It is possible one day in the future, after all plants and animals have reached their physiological maximum in production, that virtually all agricultural research will be of a maintenance nature. Of course, this research still can have a high pay-off to society; without it the stock of knowledge would decline and along with it our output and agricultural productivity.

Before I turn to attempts to measure the value of knowledge produced by agricultural research, one should be reminded that the output of new knowledge does not occur immediately upon application of scientific inputs. Our knowledge of this lag between inputs and output is still quite meager but the available evidence suggests it is in the range of 6 to 8 years.[1/] Thus the research being done in 1975 will most likely

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1/ Robert Evenson, "The Contribution of Agricultural Research and Extension to Agricultural Production," Unpublished Ph.D. dissertation, University of Chicago, 1968.

have its major impact during the 1980's. The lag appears to be longer for the more basic research than for more applied efforts. Also it is reasonable to believe the lag is longer for livestock research than it is for crops and poultry because of the differences in time required for generations to reproduce. And the longer we have to wait for an investment to pay off, the greater the cost of the investment because in the mean time the money or resources invested could have been yielding a return in other uses.

In order to evaluate the attractiveness of agriculture research as an investment we must have a measure of both its costs and returns. Cost figures, at least for public expenditures in the aggregate are quite readily available and therefore pose no problem. Measuring the value of knowledge is another matter. It doesn't come in easy to measure units such as bushels, pounds, or dollars. Thus we are forced to use an indirect measure of its value.

As mentioned, agricultural research makes possible new, more productive inputs for agriculture, which incidentally may include the farmer himself. (The farmer who learns how to balance a ration and to coax more output from his beef or dairy herd is in a sense a new input). However when the U.S. Department of Agriculture measures the total quantity of inputs in agriculture, some of these input quality improvements are not reflected in the input measure. For example, the farmer who has learned how to balance a ration inters the input measure in the same quantity after as before he gained this information. Of course, the additional output that results from this information or other input quality improvements is reflected in the output measure. Consequently output increases while the measure of inputs remains unchanged. Basically this is the reason for the growth in productivity, or output per unit of inputs, in U.S. agriculture. We have obtained large increases in agricultural output without proportionate increases in inputs because our measure of inputs have not fully reflected quality improvements. Between 1930 and 1972 total agricultural output increased by 115 percent, while measured inputs increased by only 10 percent. As a result productivity increased by 105 percent

Table I. Indexes of Output, Inputs, and Total Factor Productivity in U.S. Agricultual Selected Years

Year	Output	Inputs	Productivity
1930	100	100	100
1940	115	100	115
1950	141	104	137
1960	174	104	170
1972	215	110	205

Source: U.S. Department of Agriculture, "Changes In Farm Production and Efficiency" Statistical Bulletin No. 233. 1964, pp. 49-50 and 1973 pp. 5 and 30.

II Benefits of Research

So far I've argued that agricultural research increases the quality of agricultural inputs. Higher quality inputs cause agricultural output to increase. And the increase in output results in an increase in productivity. Although the changes in input quality are hard to detect and measure, it is easy to observe increases in productivity. Hence the value of the output of research can be estimated by the value of the additional agricultural output that is obtained due to productivity growth. We know how much output is obtained from changes in traditional inputs, the remaining output is credited to higher input quality.

Quality improvements in inputs will continue to increase output year after year far into the future, and in so doing yield a stream of returns. Thus it is proper to view agricultural research as an investment much like a new building or machine. And it is common to evaluate the profitability of an investment by its rate of return. By viewing research expenditures as the cost of the investment and the annual value of added output as the stream of returns, we can calculate a rate of return to research.

Our calculations reveal that the rate of return to additional investment in agricultural research and extension has been in the neighborhood of 45 to 50 percent per year over the past 40 years.[2/] It is like the

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2/ Willis Peterson and Joseph Fitzharris, "The Organization and Productivity of the Federal-State Research System in the United States," University of Minnesota, Agricultural and Applied Economics Staff Paper P74-23 October 1974, p. 40.

nation placing its annual research and extension expenditures in a savings account and enjoying a 50 percent rate of return.

Part of the return to agricultural research comes in the form of a more abundant supply of agricultural products which results in a lower real cost of food to consumers. In spite of the seemingly high prices at supermarkets these days, food is cheap. People living in the poorer nations of the world spend on the average 80 to 85 percent of their incomes on food. When a family has to spend 80 percent of its income on food, food is expensive. Americans spend about 16 percent of their incomes on food. For Americans, food is cheap relative to what it was years ago, or in comparison to what it is for people living in the less developed nations.

Not only is food cheaper in the United States today than in any other country of the world or ever before in history, but it is of the highest quality that people have ever enjoyed. If U.S. consumers were willing to settle for the quality of food that is now being sold in the poorer nations, or forego the processing and services connected with their food purchases they would be spending a good deal less than 16 percent of their incomes on food.

The other part of the return to agricultural research is the release of traditional resources from agriculture, mainly labor. As agricultural productivity increases, and food becomes more plentiful and lower priced, incomes in agriculture decline relative to incomes in nonfarm occupations. As a result people leave agriculture in search of higher incomes elsewhere. This is the adjustment that took place in the United States during the 1950's and 1960's, when during the peak years one million people left agriculture annually. These people now are helping to produce such things as housing, automobiles, appliances, education, medical care, travel service, and the 1001 other things that increase our standard of living. A nation that has to employ 70 to 80 percent of its people to produce food cannot produce much of anything else. Hence its standard of living is low. Two hundred years ago it took about 85 percent of the U.S. population to produce its food. Now it takes about 5 percent. Without the increase in agricultural productivity made possible by agricultural research, we would still be an underdeveloped country. This points out the key role that agriculture plays in economic development.

This is not to say that growth in agricultural productivity is the only thing that has contributed to the high standard of living in the United States. Certainly education and scientific advances in other industries have made equally large contributions to our well being, as well as the tremendous amount of conventional investment on such things as machines and buildings. But without the growth in agricultural productivity, which makes it possible for other things to be produced, we would not have them. People must have food before they can turn their attention to producing other things.

When assessing the benefits of agricultural research we should not forget the affect of lower food prices on low income people. Because food makes up a larger fraction of the budgets of low income people compared to their higher income counterparts, the relative benefits of lower food prices are bestowed more generously on the poor than on high income people. Increasing the purchasing power of poor people is like giving them more money to spend, and as such agricultural research has served as an effective device to redistribute income.

Before leaving the discussion of the benefits of agricultural research, I would like to clarify the roles of public extension and private research. In evaluating the rates of return to research quoted a few minutes ago, (the 45 to 50 percent figures) the cost figures included public extension and private research. Public extension amounts to about one-third of the total one billion plus dollars spent in 1975. Information on private research is very sketchy. Our best estimate is that private research by farm supply companies, is about equal to that of public research and extension. Thus we estimate the total public and private research expenditure by doubling the public research figure.

Including both public extension and private research in the cost of research figure probably results in fairly conservative estimates of the overall rate of return to research. The returns to public extension expenditures should really be evalutated separately. It is not realistic to assume that the new knowledge produced by research would never be utilized without extension. It is more reasonable to believe that extension speeds up the rate of adoption of new technology. The benefit of extension, therefore, is the value derived from farmers adopting a new input or technique more quickly than they would without the extension. About the only evidence available on the rate of return to investment in extension comes from a study on the affect of extension on the adoption of nitrogen fertilizer in the corn belt. The figures obtained are in the range of 1.3 to 16 percent as the rate of return to investment in extension.[3/]

Including private research of farm supply companies with the public expenditure also is not strictly correct. We know that the private return to private research is derived from the price of the inputs sold to farmers. Thus higher quality or new inputs must sell for a higher price in order for farm supply firms to recoup a return to their investment in research and development. As a result the measure of inputs which is used to compute agricultural productivity already includes the amount that it cost private firms to increase input quality. This means that the cost of private research is in a sense counted twice; once on the cost side by including it in the double research bill, and again on the returns side because the higher input cost increases the measure of inputs and therefore reduces productivity and the measured returns to research. Thus our procedure for estimating the rate of return to research yields fairly conservative estimates.

It probably is not well recognized that private research benefits society in the same way as public research and that the social returns to private research have to be greater than the private returns. By social returns I mean the value of the additional farm output that is obtained

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3/ Wallace Huffman, "Decision Making: The Role of Education", American Journal of Agricultural Economics, February 1974, p. 95.

from higher quality inputs made possible by private research. We know farmers will not purchase inputs from farm supply firms unless the contribution of the inputs to farm output is at least as great as their price or cost to the farmer. Otherwise there would be no incentive for farmers to buy these inputs. We also know that the price of these purchased inputs must include a private return to the private research that was done to develop the input. This is the only way that private firms can recoup their research costs. Because the added contribution to farm output must be at least as great as the input price, the social returns to private research must be greater than the private returns.[4/]

The Next 100 Years

What does the future hold in store for agricultural research over the next 100 years? Of course no one knows the answer to this question. And it would serve little purpose for me to engage in pure speculation. About the only ones to come close to predicting present technology have been the science-fiction writers. Everyone else has been too conservative. But there may be some value in briefly considering the factors that should bear upon the future profitability of agricultural research.

One very important difference between 1975 and 1875 is the large stock of intellectual capital that has been produced by the 100 years of investment in research, both agricultural and nonagricultural. The larger the

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4/ At the margin the private returns should just equal the social returns if both farmers and farm supply firms maximize profits. But the social returns will be greater than the private returns for the inframarginal units.

stock of capital the more productive is human effort. If the production of knowledge (through research) is like the production of conventional goods, the increased stock of intellectual capital should have the affect of making scientists even more productive in the future. Many things that were major puzzels to scientists 100 years ago now are rountinely taught in undergraduate science courses.

At the same time we have to recognize that scientists have unlocked many of natures secrets during the past century. If the most accessible secrets have been discovered, then it may become more and more difficult to make scientific breakthroughs. For example it was fairly easy to increase corn yields through hybridization but soybeans appear to be a tougher nut to crack. If the difficulty of producing new knowledge increases then the productivity of research may decline in spite of the greater quantity of intellectual capital available to scientists.

If the potential stock of knowledge is finite, then at some point we will run into diminishing returns to research. Eventually the increased difficulty of making discoveries will more than offset the greater stock of intellectual capital. Whether this could happen in the next 100 years is not certain. Nor is it certain that the potential stock of knowledge is finite. Will anyone ever be able to say with certainty, we now have discovered everything that could add to our knowledge? I doubt it, but of course I don't know.

It probably is not very fruitful to spend much time on the philosophical question of the limits of knowledge. There are more immediate questions to be faced. One such question bears upon the allocation of research. Are the experiment stations allocating their research budgets in such a way as to maximize the returns. Experiment stations will maximize the total returns of a fixed research budget only if the rates of return for research investment in the various research areas are equalized. In other words, the rate of return to investment in crop research should be made equal to that of livestock research. And the same thing is true of all the individual crop and livestock categories. If the rate of return in one area is higher than that of another, then the total returns can be increased by shifting some research away from the low to the high return area.

Granted this is a very difficult task. Because research is such an uncertain activity with regard to pay-off, it probably is not realistic to strive for equal rates of return on individual projects or even within relative narrow research areas. For one thing no one can know the actual rate of return to an individual project until long after it is completed. It's actual return will depend also on the skill and luck of the researcher.

As we look at relatively broad research areas, the evidence suggests that for the country as a whole the rates of return to investment in cash grains, livestock, dairy, and poultry research appear to be fairly close together in the range of 40 to 50 percent.[5/] However, there does appear

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5/ Maury Bredahl, "Marginal Productivity and Allocation of Agricultural Research in U.S. Agricultural Experiment Stations," Unpublished Ph.D. Dissertation, Dept. of Agr. and Applied Econ., University of Minnesota, 1975.

to be quite a bit of variation in rates of return to investment in research both between and within experiment stations. Rates of return seem to be highest for the major crop and livestock categories within states. For example, in the corn belt states rates of return to cash grains research tends to be higher than it is in the major livestock producing states even though the total cash grains research is greater in the cash grains producing states. A useful guideline is the dollars of related output per dollar of research. For example, a state which has $700 of cash grains output per dollar of research is likely to exhibit a higher rate of return to this research than a state which produces $350 of cash grains output per dollar of research. Thus it would seem prudent for a state not to allow dollars of output per dollar of research to deviate too much below the national average for each major research category unless it is fairly certain that the department is unusually productive or a "center of excellence" in its discipline.

Regarding the allocation of research within departments, I'm skeptical that research administrators at least above the departmental level, can do much to improve the research allocation. Granted, because of limited research funds, administrators are forced to screen research proposals, accepting some and rejecting others. But it seems to me that the individual scientist still is in the best position to propose research. It takes a great deal of specialized, up to date information about the frontiers of knowledge in a discipline to know what should and particularly what can be done. By nature of his (or her) work, the research administrator does not have access to such information to anywhere near the extent of the scientist. The comparatively decentralized decision making agricultural research system we have had in the United States over the past 100 years has been very successful. We ought to be very careful about changing an already successful system.