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RETURNS TO INVESTMENT IN AGRICULTURAL RESEARCH

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Returns to Investment in Agricultural Research

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In 1978 U.S. taxpayers will be called upon to pay in excess of 1.5 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 $1.5 billion represents a relatively small part of the total federal and state budgets, and amounts to about $20 per family per year, it still represents a great deal of money and resources, and we ought to ask, what does society get from this expenditure? Before attempting to answer this question, I should mention that expenditures on agricultural research and development (R & D) by private firms in the farm supply industries are believed to be at least equal to and perhaps greater than public expenditures in this area. But we have not been greatly concerned about the payoff to private investment in agricultural research because firms would not invest if it were not profitable and we can be reasonably sure that if this investment is privately profitable it is also socially profitable (Peterson, 1976). The focus of this paper is on social returns which can be thought of as the additional output that society obtains from both public and private investment in agricultural research. Private returns are simply the extra revenue generated by firms which invest in research.

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Research and Productivity

It is helpful to view agricultural research as a production activity having both inputs and an output. The principle inputs consist of scientific personnel, laboratory facilities, test plots, libraries, computers, etc. The output is new knowledge. This knowledge comes in several forms and is utilized in a variety of ways. In its most basic form it can further our understanding of nature and allow us to make technological advances that otherwise would 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 the nutrient requirements of livestock or about cultural practices that increase crop yields. Some of the knowledge is utilized by the farm supply industries in conjunction with that which is produced by their own R & D to create new, more productive inputs for agriculture, such as new labor saving machines or the host of chemical inputs that help control weeds, insects, and diseases. In summary, we can say that agricultural research produces new knowledge which in turn creates or makes possible the production of new, more, efficient inputs for agriculture.

Also it is important to recognize that knowledge is a form of capital. As such it shares some common characteristics with the more conventional forms of capital such as buildings and machines. First it pays off over a long period of time. For example, current generations are still benefiting from early advances in mechanization, genetics, and plant physiology. Secondly, the production of knowledge in most cases is characterized by a substantial gestation period. The available evidence suggests that the lag between research inputs and the output of knowledge is in the neighborhood of 6 to 8 years (Evenson, 1968). As expected the lag appears to be longer for basic research than for the more applied work. Also one might expect it to be longer for livestock research than for crops and poultry because of the differences in time required for generations to reproduce. The existence of the gestation period, or lag, together with the long payoff period requires that we accumulate costs and discount returns in evaluating the profitability of research.

Before turning to the methods used to evaluate agricultural research, one additional similarity between knowledge and more conventional forms of capital ought to be mentioned. Both tend to depreciate and require annual maintenance just to remain intact. Scientists along with everyone else grow old and pass from the scene. Their knowledge must be passed on to younger generations. Much of what goes on in our educational institutions 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 are produced that make the old ones obsolete. For example, the modern combine has replaced the old threshing machine which at one time was a new, more productive input itself. Thus a sizeable fraction of the annual expenditure on agricultural research is for maintenance purposes. It is possible at some future date when (or if) all plants and animals reach their physiological limits of production that virtually all research will be of a maintenance nature. Of course this research still could have a high payoff to society; without it the stock of knowledge would decline and as a result we would likely experience a decrease in agricultural output and productivity.

In order to evaluate the attractiveness of research as an investment we must have a measure of both its costs and returns. Cost figures, at least for public expenditures, are available and therefore have not been a major 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 indirect measures of its value.

As mentioned, agricultural research makes possible the production of new, more productive inputs for agriculture, which may include the farmer himself. (The farmer who learns how to balance a ration and in so doing increases the feed efficiency of his livestock 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 measure of total inputs. For example, the farmer who has learned how to balance a ration is counted as the same quantity after as before he gained this information. Of course, the additional output, or savings in conventional inputs such as feed, which result from this information are reflected in the measures of output and conventional inputs. Consequently we observe an increase in output per unit of input, i.e. an increase in productivity. Basically this is the reason for the growth in productivity, or output per unit of input, in U.S. agriculture. We have obtained large increases in agricultural output without proportionate increases in inputs because our measure of inputs have not reflected quality improvements. Between 1930 and 1975 total agricultural output in the United States increased by 119 percent, while measured inputs increased by only 8 percent (Table 1). As a result total factor productivity increased by 111 percent.

Table 1. Indexes of Output, Inputs, and Total Factor Productivity, U.S. Agriculture Selected Years

Year	Output	Inputs	Productivity
1930	100	100	100
1940	115	100	115
1950	141	104	137
1960	174	104	170
1970	197	109	188
1975	219	108	211

Source: U.S. Department of Agriculture, Agricultural Statistics, respective years.

Benefits of Research

Thus far I've argued that agricultural research increases the quality of inputs in agriculture which in turn results in an increase in productivity due to our inability to accurately measure these quality changes. The question I now turn to is how does an increase in agricultural productivity benefit society? Part of the benefit 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 in supermarkets these days, food is relatively cheap in comparison to what we have to give up to obtain it. It is not uncommon for people in the less developed countries (LDCs) to spend 80 to 85 percent of their incomes on food. Two hundred years ago, Americans also spent 85 percent of their incomes on food. When a family has to spend 80 to 85 percent of its income on food, food is expensive. People in the United States now spend on the average 16 percent of their incomes on food. For Americans, food is cheap relative to what it was in years past or what it is for people in other nations particularly the LDCs.

The great decline in the proportion of our time or income required to buy food becomes even more remarkable when we consider the increase in quality and services that are purchased along with food in the United States and other developed countries. The increase in quality has two dimensions: one is the reduction in disease damage and disease organisms found in the food, and other is the increase in the proportion of animal products in our food which is more expensive to produce than food taken directly from plant sources. Equally important is the very large increase in services that are purchased along with food which also increases its cost from what it would otherwise be. If U.S. consumers were willing to settle for the quality of food purchased by our ancesters and is now being purchased in the LDCs, or to forego the processing and convenience services connected with food they would be spending a good deal less than 16 percent of their income on food. Of course, this is not to criticize people for wanting to spend part of their increased earnings on higher quality and more convenient forms of food.

A second source of benefit from agricultural research is the release of conventional resources from agriculture, mainly labor. As agricultural productivity increases, and food becomes more plentiful and lower priced, incomes in agriculture decrease relative to incomes in nonfarm occupations. As a result people have an incentive to leave agriculture in search of higher incomes elsewhere. This is the adjustment that took place in the United States during the 1950s and 1960s, when during the peak migration years one million people left agriculture annually. This adjustment now has run its course. People that otherwise would be in agriculture were it not for the new technology made possible by research now are helping to produce such things as housing, automobiles, appliances, education, medical care, travel services and the 1001 other things that serve to increase our standard of living. A nation that must employ 70 to 80 percent of its working population 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 about 5 percent of our people live on farms, although one should include people in the farm supply industries as being indirectly involved in food and fiber production. At any rate, without the increase in agricultural productivity, we would be doing without the output now being produced by displaced farmers. This points up the key role played by agricultural research in the process of economic development.

This is not to say that the growth in agricultural productivity is the only thing that has contributed to our high standard of living. Certainly, a high level of education and scientific advances in other industries have made equally large contributions, as well as the tremendous amount of investment in conventional capital such as buildings and machines. But without growth in agricultural productivity, people will not be able to leave agriculture to produce other consumption and capital goods. Food is of the highest priority when it comes to human survival.

When assessing the benefits of agricultural research we should at least mention the special benefits that accrue to low income people. We know that agricultural research increases the supply of food and lowers its real price. We know also that food makes up a larger fraction of the budgets of low income people than those with high incomes. Thus the benefits of agricultural research are bestowed more generously on the people with low incomes than on those with high incomes. Increasing the purchasing power of low income people is like giving them more money to spend. As such agricultural research has served as an effective device to redistribute purchasing power in favor of low income people, although it is not widely recognized as having this effect.

Methods of Measurement

Two separate but related methods have been used to measure the monetary returns to agricultural research: one I refer to as the index number approach, the other the production function approach. With the index number approach a productivity index is used to measure the impact of research on producitivity. This can be a total factor productivity index such as presented in table 1, or a partial productivity index such as yields per acre. The monetary value of the increase in productivity has been measured in two ways. One method is to measure the value of conventional inputs saved in producing a given level of output (Schultz). The other is to measure the value of additional output obtained from a given level of conventional inputs (Griliches 1958; Peterson 1967). The value of this additional output resulting from the increase in productivity sometimes is referred to as "consumer surplus", reflecting the idea that the ultimate beneficiaries of agricultural research are consumers.

With the production function approach, research expenditures are included as a separate variable or input in an agricultural production function (Griliches, 1964; Peterson, 1967; Evenson, 1967; Bredahl and Peterson, 1976). The research variable "picks up" the variation in output that is not accounted for by the variation in conventional inputs. Perhaps the main advantage of the production function approach is that the measured impact of research on production is amenable to statistical testing. As such, this method constitutes a somewhat more rigorous measure of the impact of research on output. However, the index number approach is a bit less demanding in terms of data requirements.

Rates of Return

Because research is an investment the comparison between monetary costs and returns is best expressed as a rate of return. Most recent estimates of the rate of return to investment in agricultural research in the major commodity areas range from 36 to 46 percent (Table 2). These figures were obtained using the production function approach.

From these results it appears that the rate of return to investment in agricultural research is about three times the 12 to 15 percent before tax rate of return that is obtained from conventional investment in manufacturing.

Table 2. Internal Rates of Return to Investment in Agricultural Research

Commodity Area	Rate of Return (%)
Livestock	46
Dairy	43
Poultry	37
Cash grains	36

Source: Bredahl, Maury, and Willis Peterson, "The Productivity and Allocation of Research: U.S. Agricultural Experiment Stations" Am. Jour. Agr. Econ., 58(1976): 684-92.

It should be pointed out however, that the above estimates were derived from 1969 Census of Agriculture data and 1969 prices. One might reasonably ask, can these estimates be used with any degree of certainty to predict the returns to current and future research? The answer to this question depends on two important criteria: the production elasticity of research and the dollars of related output per dollar of research. The higher each of these values, the greater the returns to research. The production elasticity of agricultural research is defined as the percent change in agricultural output resulting from a one percent change in research. It is a parameter that is estimated by the production function. In order to be able to predict the returns to current and future research from past experience, we have to be reasonably certain that its production elasticity will not decline in the future. Although no guarantee can be made that it will not decline, the results of past studies suggest that the production elasticity of U.S. agricultural research in the aggregate has remained comparatively stable at about .06 from 1949 to 1969 (Griliches 1964; Bredahl and Peterson). To my knowledge nothing has happended in the last few years that would lead us to believe this value has declined or is about to decline.

This takes us to the second criterion: dollars of agricultural output per dollar of agricultural research. Because of an increase in both the volume of agricultural output and farm prices during the early 1970's, this figure increased from 72 in 1969 to 94 in 1973 (Table 3). Thus if we were to compute rates of return to research in the four major commodity groups using 1973 output and prices they would be somewhat higher than the figures presented in table 2. But generally it doesn't pay to worry about year-to-year

Table 3. Public Agricultural Research and Extension and Farm Output, $ Million, United States, Current Prices, Selected Years.

	Research and Extension				Farm	Dollars of Output
Year	SAES	USDA	Ext.	Total	Output	Per Dollar of R & E
1949	$39.9	$46.0	$67.2	$153.1	$30,817	$201
1954	68.0	46.0	91.6	205.6	33,332	162
1959	110.3	99.0	136.0	345.3	36,786	106
1964	169.3	149.8	177.9	497.0	40,386	81
1969	274.0	213.2	242.0	729.2	52,515	72
1973	382.9	303.9	385.1	1071.9	100,582	94

Sources: SAES: 1954-59; "Report on the Agricultural Experiment Stations", Agricultural Research Service 1964-73; "Funds for Research at State Agricultural Experiment Stations" Cooperative State Experiment Station Service. U.S. Dept. of Agriculture.

USDA: "Appropriations for Research and Education" prepared by the Office of Budget and Finance, U.S. Dept. of Agriculture.

Extension: 1954. "Annual Report of Cooperative Extension Work in Agriculture and Home Economics," U.S. Department of Agriculture, 1959-73: Unpublished data from the extension service.

Farm output: Defined as cash receipts from farming plus value of home consumption. Agricultural Statistics, respective years.

fluctuations in dollars of output per dollar of research. Mainly we should be interested in long run trends. Here we see that there has been a long term decline in dollars of agricultural output per dollar of research since the end of WWII (table 3). In 1949 it was $201. The figure declined to $72 in 1969. Although the official statistics are not available for 1977, my best guess is that the figure is down to about its 1969 level in the neighborhood of $70. (The main reason for the sharp drop from 1973 to 1977 is the substantial decline in farm prices). Whether the figure continues to decline in the future depends on whether agricultural research and extension expenditures continue to grow more rapidly than the value of farm output. The figure probably could be pushed down to about half of its 1977 level before we needed to start worrying that the rate of return on agricultural research might be lower than the return on conventional investment. Since the rate of decline has decreased during the past decade and shows signs of leveling off there doesn't appear to be any immediate danger of this happening.

Research Allocation

The fact that agricultural research in the aggregate appears to be paying off handsomely doesn't mean, of course, that all research within that aggregate is equally productive. The evidence suggests that the rate of return to research varies considerably both within and between experiment stations. (Bredahl and Peterson) Although there appears to be some difference in the size of the production elasticity of research between commodity groups, the major reason for differences in estimated rates of return within stations is the variation in dollars of related output per dollar of research. In general the larger commodity groups within states exhibit more dollars of output per dollar of related research than the smaller groups. It is not uncommon to observe differences of the order of magnitude of 10 to 12 times. For example, in Kansas dollars of output per dollar of related research is about 12 times larger for livestock than for poultry. In Arkansas the situation is just reversed where the poultry figure is over 12 times larger than the livestock figure. Although states do allocate more research money in total to their large and most important commodity groups, the difference usually is not of the same proportion as the difference in output. As a result the estimated rate of return tends to be higher for the large commodity groups than for the small ones within any given state.

Similar conditions appear to exist between states. For any given commodity group, dollars of related output per dollar of research tends to be higher in states where the commodity is a large and important part of the states' output. For example the dairy figure in Wisconsin is over 3 times what it is in Iowa, but the Iowa figure for livestock is nearly 5 times that of Wisconsin.

In order to maximize the rate of return to the nation's expenditure on agricultural research, research money should be allocated such that the rates of return to each of the commodity groups are equal. This doesn't necessarily imply dollars of output per dollar of research should be equal for all commodities in all states. As mentioned there appears to be some difference in the production elasticity of research between commodity groups. Perhaps more important, one should allow for the possibility of differences in production elasticities between departments. Although we have not been able to detect a significant difference in the production elasticity of research between size groups of departments, this doesn't mean that individual differences do not exist. A high quality department that has become a center of excellence in its field likely would exhibit an above average production elasticity and could therefore earn a high rate of return even though it might have a below average figure on output per dollar of research. Thus there is still plenty of room for the use of good judgement in the allocation of research resources. Figures on dollars of related output per dollar of research is just one piece of information that can be useful in making allocative decisions. Unless there are some compelling reasons for not doing so, moving in the direction of more equality between these figures is likely to improve the overall rate of return to research.

Allocative decisions must also be made at the individual project level within departments. However, at the project level the use of formal economic analysis to predict payoffs is a very risky endeaver, mainly because research itself is so risky. Research is somewhat like drilling for oil; it is virtually impossible to predict in advance whether a project will turn out to be a "gusher" or a "dry hole". The outcome depends largely on the skill or competence of the scientist. Probably the best predictor of the outcome of an individual project is the recent "track record" of the scientist proposing it.

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