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POTENTIAL RETURNS FROM INCREASED RESEARCH BUDGET FOR THE LAND GRANT UNIVERSITIES

By K. William Easter and George W. Norton*

Investment in U.S. agricultural research is substantial and it continues to expand. Numerous studies have shown that past agricultural research expenditures have high rates of return. However, private investment in agricultural research is restricted since many of the research benefits cannot be captured by a private firm.¹ Thus, the public sector must do much of the basic agricultural research. Among the key institutions in this public research capacity, including dissemination of the results, are the agricultural experiment stations and the extension services in the land grant universities.

Abstract: With the growing competition for Federal dollars, the land grant universities were asked to justify their budget to the Congress and the Office of Management and Budget using benefit-cost analysis. The authors review previous studies of returns to agricultural research and present an analysis of corn and soybean research that formed part of these universities' 1978 budget request for Federal monies. New research to increase corn and soybean production would bring very high returns, and consumers would be the primary beneficiaries. The large acreage affected by the research was an important reason for these high returns. Consumers would benefit from lower prices and the resulting increase in consumer surplus. Keywords: Benefit-cost, consumer surplus, agricultural research, corn, soybeans.

As competition grows for both Federal and State budget funds, the land grant universities have been asked to provide projected rates of return or benefit-cost analyses of their research and extension budget requests. To help respond to such requests from the Office of Management and Budget (OMB) and the Congress, a Committee

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¹ However, for agricultural research such as seed and pesticide development, private firms can capture enough benefits and they contribute substantially to such research.

on Program Analysis for the USDA Budget was established in 1976 to begin to apply such analysis to budget requests from the agricultural experiment stations and the extension services. The analysis we present formed part of this committee's work and it was used to help justify these universities' 1978 USDA budget request to OMB.

We briefly review approaches used to assess returns to U.S. agricultural research and explain the usefulness of benefit-cost analysis in such evaluations. We then apply such analysis to the land grant universities federal budget requests for additional funds for corn and soybean research in the North-Central region.

REVIEW

The first major attempt at quantitative evaluation of agricultural research investments was conducted by T. W. Schultz (16).² He calculated the value of inputs saved in agriculture because of improved production techniques and compared this with the costs of research and development. His effort was followed by that of Griliches (5) who calculated the loss in consumer surplus that would occur if hybrid corn were to disappear. His analysis assumed that the adoption of hybrid corn shifted the supply curve of the product downward to the right. He estimated the returns in the two polar cases of perfectly elastic and perfectly inelastic supply elasticities. In each case, the area below the demand curve and between the original and the shifted supply curves constitutes the estimated amount of the returns.

Peterson (15) generalized Griliches' formula for estimating consumer surplus and applied it to poultry research. He calculated the case wherein supply is neither perfectly elastic nor perfectly inelastic and did not require a demand elasticity of one as Griliches' formulas did. Peterson says that the biggest problem with his and Griliches' method (which he refers to as the index number approach) is that of obtaining a measure of productivity gain that reflects only the output of research (14).

In another study (6) Griliches was perhaps the first to use an aggregate production function approach to estimate a marginal product of research. A marginal return is more useful than an average return to decisionmakers

² Italicized numbers in parentheses refer to items in References at the end of this article.

studying the merits of new research projects. Evenson (2) also calculated a marginal product of aggregate agricultural research expenditures. In addition, he estimated that the returns over time first increased and then decreased and that the high point occurred after about 6 years.

Tweeten and Hines (20) employ a different approach in their study of the returns to aggregate agricultural research. They calculate how much lower the national income would be if the percentage of people on the farm remained the same as in 1910 and if the resulting additional farmers had the income of today's farmers instead of today's nonfarmers. They estimate the costs of public and private research, education, and Federal programs and calculate a benefit-cost ratio.

Fishel (4) describes a computerized model for collecting and processing information needed to evaluate research activities and to select an efficient allocation of resources. He stresses the importance of recognizing that there is a probability distribution around likely benefits from research. To obtain the information needed to arrive at a subjective probability distribution, scientists were asked to predict (1) the most likely outcome as well as high and low outcomes that would be exceeded only one-third of the time and (2) high and low outcomes that would be exceeded only in very exceptional circumstances. Application of the model required a fairly extensive set of surveys.

Bredahl and Peterson (1) look at the differences in rates of return to various kinds of agricultural research (cash crops, dairy, poultry, livestock) to determine if the overall rate of return could be increased by reallocating some research resources from the low to the relatively high return activities. They utilize aggregate agricultural production functions in which research is a separate independent variable to estimate the marginal products of research.

Another research evaluation procedure has been used involving various types of scoring models. These models do not provide quantitative estimates of benefits and costs but rank the research alternatives. The National Association of State Universities and Land Grant Colleges and USDA published in 1966 the results of a study of agricultural and forestry research programs in the United States (22). The study evaluated the strengths and weaknesses in the research program, identified future research problems, and recommended a level of public support for agricultural research for a 10-year period. A major result was the systematic classification of research areas. (A subsequent publication, (23), lays out the classification system in detail.) A simple scoring model was used to determine the extent to which each research priority area met certain criteria. Each specified criterion was weighted in terms of importance. This system was used to bring out facets of a problem that otherwise might have been overlooked, but it was not employed as a mathematical basis for allocating resources.

Another study which used a simple scoring scheme to rank research problem areas was done in Iowa to aid in the allocation of resources at the Iowa Experiment Station (9, 11). This study was one of the first, along with the Fishel study cited above, to give explicit consideration to the importance of the probabilities of success of a research project.

Shumway and McCracken (19) also focused on a set of numerical models for ranking recommended resource reallocations at the North Carolina Agricultural Experiment Station. The goal was to determine which research problem areas should be emphasized over the next 5 years. Various people scored the research program areas (RPA's) which were then ranked.

The majority of agricultural research evaluation studies have fallen, therefore, into three basic classes: (1) the study of returns to aggregate agricultural research; (2) the study of returns to research on individual commodities; and (3) the use of models which are designed to rank alternative research projects or problem areas within an individual agricultural experiment station or nationally. Most studies in the first two categories are oriented toward the past while those in the third are oriented toward evaluating research for the present or future.

As a practical matter, the Federal Government must evaluate experiment station requests for additional funding annually, and this evaluation must be completed in a short period of time. The classification scheme developed in the USDA-SAES study aids in delineating where funds might be used. Studies which have evaluated returns to past research do provide many valuable insights into the value of future research. However, there has been little quantitative *ex ante* estimation of returns to research.

Some have suggested that benefit-cost analysis can be used to provide this *ex ante* evaluation. Fedkiw and Hjort (3) believe that benefit-cost analysis can be a useful tool if sensitivity analysis is used and scientists are asked to provide an opinion on the probability of success of each project. The determination of a benefit-cost ratio can be made relatively quickly even without a computer. More skeptical about the adequacy of the methodology, Williamson (24) stresses that unless active support is obtained from the scientists, reliability of estimates will be seriously impaired. Peterson fears that widespread use of benefit-cost analysis could be very costly; some projects require more resources to evaluate than are in the project budget (13). Paulsen and Kaldor stress the importance of keeping the benefit-cost analysis simple (11).

The above comments suggest two important questions: (1) What information is required to estimate benefit-cost ratios for future research expenditures? and (2) How can this information be analyzed in a manner that is not misleading and yet is simple enough so it does not exceed the time and resource constraints placed on the evaluation process?

CORN AND SOYBEAN RESEARCH

The North-Central region's research request was evaluated by the USDA Budget Committee because the increase in corn and soybean research funds is concentrated in that region.³ The analysis was further narrowed to include only the new research in the two research program areas (RPA's) with the largest requests:

- (1) RPA's 207-209: Crop protection from insects, diseases, and weeds for corn and soybeans
- (2) RPA 307: Improvement of biological efficiency of crop production for corn and soybeans

Scientists from the land grant universities provided estimates of yield and cost effects and adoption rates for technology developed with the new research funds. The low end of their range of estimates was used in the analysis (table 1). To calculate the benefit-cost ratios for each RPA, the following assumptions were made: (1) a discount rate of 10 percent, (2) harvested acreage held constant at the 1975 level, (3) corn and soybean quality remaining constant or the increase in quality not lowering livestock feeding costs, (4) a corn price of \$2 per bushel and a soybean price of \$4.75 per bushel, (5) a probability of success of 0.8 for corn and 0.5 for soybeans, (6) the lag in adoption of new methods as shown in table 1, (7) benefits beginning in the year specified in table 1 and ending in the year 2000, and (8) research impacts occurring only in the North-Central region.

Several of the above assumptions are probably conservative. The reporting scientists estimated that pro-

duction costs would decline as a result of the increased research. They also thought that the protein quantity and quality in corn should improve because of added research in RPA 307 which would lower feed costs. However, for simplicity in the analysis, only yield increases were counted as benefits even though the cost reductions would afford the same benefits as greater yields. Finally, the prices assumed for corn and soybeans were based on projections which assume no increase in exports over the period.

Benefit-Cost Estimates

The data can be incorporated in a simple framework to arrive at the benefit-cost ratios. The ratios calculated for corn and soybeans are all extremely high (table 2). The low is \$9 in benefits per dollar cost for improvement of biological efficiency of soybeans under assumptions of long lags, limited probabilities of success, and moderate yield increases. The high is \$172 in benefits per dollar of cost for protection of corn from insects, diseases, and weeds under an assumption of relatively higher prices for corn. The benefits from corn research in the North-Central region are especially high because the yield increases occur over such a large acreage.

The importance of the acreage affected can be illustrated by considering the Southern region. There, corn acreage in 1975 was 8.8 million acres, compared with 54.7 million in the North-Central region. If the same yield increases are assumed for the Southern region, the benefit-cost ratios range from 5 to 26 for corn in RPA 307. This range is for the same research expenditure as in the North-Central region, and it assumes that the research only affects the Southern region. Benefit-cost ratios would not be reduced as much for soybeans since the Southern region's acreage is about a third that of the North-Central region.

Table 1.—Information required for estimating returns for public research to increase corn and soybean production, North-Central region

Crop	RPA	SY ¹	Dollars per SY (000)	1975 Yield	1975 area	Change in yield by year 2000	Year avail- able	Adoption pattern ²			
								1st year	2nd year	3rd year	4th and later years
		Number	1,000 dollars	Bushels/ acre	1,000 acres	Percent		Percent of total area			
Corn	207-9	2.5	77.1	88.9	54,722	2	1982	30	50	75	75
Corn	307	3.0	72.3	88.9	54,722	2.25	1985	30	60	80	80
Soybeans	207-9	1.5	69.6	31.1	33,557	1	1982	30	50	70	85
Soybeans	307	3.0	74.4	31.1	33,557	2	1985	40	70	90	95

¹ SY stands for scientist year. Dollars per SY includes the cost of the scientists' salary as well as supporting facilities.

² Adoption patterns allow for a lag in the influence of the programs. For example, the research results from RPA 207-9 will be adopted on 30 percent of the corn acreage in the year the new research is available. In the second year it will be adopted on 50 percent of the corn acreage, and in subsequent years, it will be adopted on 75 percent of the acreage.

Table 2.—Sensitivity analysis of the benefits and costs of new production research on soybeans and corn

Benefit-costs	Corn		Soybeans	
	RPA 207-9	RPA 307	RPA 207-9	RPA 307
1. Under initial assumptions	137	118	45	40
2. With longer lags	117	102	38	30
3. With lower probabilities of success	86	74	27	24
4. With both longer lags and lower probabilities	73	64	24	19
5. With \$2.50 corn and \$5 soybeans	172	148	47	42
6. With 50 percent smaller yield increase	69	59	22	20
7. With both lower yield increase and lower probabilities	43	37	13	12
8. With lags, probabilities, and yield changed	37	32	12	9

Using corn for RPA 307 as an example, benefits can be calculated for the North-Central region from table 1 as follows. Yields are expected to begin to increase under the program in 1985, rising to a level 2.25 percent above that of 1975 by the year 2000. That is a rise of two bushels per acre (88.9 times 2.25 percent) or 0.125 bushels per year for 16 years. If the probability of success is 0.8, then a gain of only 1.6 bushels is expected by the year 2000. Allowances for the adoption pattern on the 54,722,000 acres provide an estimate of the added corn production for each year.

To illustrate, in 1985, only 30 percent of the 54,722,000 acres will realize the expected increase of .125 bushels per acre. In 1986, 60 percent will have adopted the 1985 methods and 30 percent, the 1986 methods. The annual increase in production is multiplied by \$2 per bushel to estimate the total receipts or undiscounted benefits for each year. These benefits range from about \$3 million per year in 1985 to over \$133 million in the year 2000. Using a discount rate of 10 percent, this future stream of income would have been worth \$200,476,000 in 1975.

Costs are \$216,900 per year for 3 SY's at \$72,300 per SY. The value of the stream of expenditures was \$1,696,961 in 1975. The benefit-cost ratio for corn from RPA 307 is: \$200,476,000 divided by \$216,900 equals 118.14. That is, one dollar of costs is expected to return \$118, as viewed from the starting year of 1975 (table 2, row 1).

The benefit-cost ratios are sensitive to changes in assumptions concerning the length of lags, probability of success, prices, and yields. For example, scientists may tend to be overly optimistic in their estimates of future yield increases. Also in light of past research pro-

ductivity estimates made by Bredahl and Peterson (1), the yield increases seem high. To adjust for a possible optimistic tendency, three of the sets of benefit-cost ratios were calculated assuming that the yield increases were only 50 percent of the yield estimates.

As a check to see if the reduced yield increases are reasonable, all scientists from the North-Central region working on corn in RPA's 207-209 and 307 were assumed to be just as productive as the new scientists. With yield increases reduced to 50 percent and the lower probability of success, corn yields in 2000 would be 16 bushels higher because of the research. In other words, corn research in the land grant universities in the North-Central region would increase corn yields in the region by 18 percent in 25 years. Assuming only the 50-percent reduction in yield increases for soybeans, scientists from the North-Central region in RPA's 207-209 and 307 would increase yields 3 bushels, or 10 percent, in 25 years. Both outcomes seem quite reasonable in light of the past productivity of agricultural research expenditures in cash grains (1). The outcomes also indicate that the reduced yield increases are more realistic, particularly for corn.

The sensitivity of the benefit-cost estimates to changes in assumptions, concerning length of lags, probability of success, prices, and yields, appears in rows 2 to 8 of table 2. First, we extend the lag between the research expenditures and the availability of the results for adoption. The lag is increased from 7 to 10 years for RPA 307 and from 4 to 6 years for RPA's 207-209, which lowers the ratios (row 2). Second, the probability of success assumption is reduced from 0.8 to 0.5 for corn and from 0.5 to 0.3 for soybeans. Again, the ratios are lowered (row 3). Third, we increase the length of

lag and reduce the probabilities of success, both of which lower the benefit-cost ratios. Fourth, the prices of corn and soybeans are increased to \$2.50 and \$5, respectively. These prices are closer to 1976 prices and raise the ratios substantially, as shown in row 5. Fifth, the yield increases are reduced by 50 percent, and the ratios are lowered (row 6).⁴ Sixth, the yield increases and the probabilities of success are both reduced, which further lowers the benefit-cost ratios. Finally, the length of lag is increased, the probability of success reduced, and the yield increases lowered by 50 percent. These changes lower the ratios substantially but, as indicated above, the reduced yield assumptions are more consistent with past trends. Yet the ratios remain high, indicating research has a high payoff over a wide range of assumptions.

Other USDA budget committee members similarly analyzed new research for wheat, beef cattle and forages, dairy and swine, and results could also be generalized to other crops and livestock.⁵ The analysis could be applied to the research base as well, although it would be more difficult to ignore the following questions. How much research is necessary just to maintain current levels of production and how important is the interaction among different types of research projects and among scientists? Can one evaluate corn breeding research separately from that for wheat breeding or new pesticides?⁶ Adjustment problems will be more important if the total research base is evaluated. Will the increase in production due to research reduce farm incomes enough to drive large numbers of farmers out of business (7)?

⁴ Note that a 50-percent reduction in the acreage affected by the new research would have the same impact as the yield reduction. However, the adjustment implied by such a large reduction in acreage would mean an increased rate of farmers moving out of agriculture and more declining rural communities.

⁵ The benefits from beef cattle-forage research were measured in terms of reproductive efficiency, reduced cow maintenance costs, and lower costs per pound of gain. Swine research benefits were measured in a similar manner. For dairy cattle, increased milk production per cow and improved reproductive efficiency were used to measure benefits. Research to improve animal health will likely be important for all classes of livestock and will be reflected in several of the benefit measures. For example, improved animal health could improve reproduction efficiency and reduce the cost per pound of meat or milk.

⁶ A more difficult task would be to evaluate the rural development research and extension. It is much more difficult to put a dollar value on rural development extension than on an additional bushel of corn. Thus, in evaluating rural development research and extension, cost-effectiveness analysis may be more appropriate than benefit-cost analysis because benefits need not be valued. Cost-effectiveness analysis would require three kinds of information: (1) a listing of specific objectives, (2) a cost breakdown by project and objective, and (3) a display of projected outcomes in physical terms, if possible. Finally, the proposal should be compared with the cost of alternative methods of obtaining similar results.

Distribution of Benefits

The benefit-cost ratios reveal nothing about the distribution of benefits between farmers and consumers. Benefits and costs of increased production are passed along to society in many ways. The additional corn and soybeans will move through markets and generate employment as well as other economic activity. Increased supplies will create downward pressure on prices which reduces the value of the increased production to farmers and raises the benefits to consumers.

Lower corn prices cause downward pressure on livestock prices as feed becomes cheaper. The impact of lower livestock prices spreads to the wholesale and retail sector and benefits consumers. Lower soybean prices have a similar effect on livestock prices and also affect the markets for margarine, shortening, and salad oil (12). The effects spread through a wide portion of the agricultural sector and, to a certain extent, the foreign trade sector as well.

To help measure the distribution of the research impact, we used estimates published in a recent report by the National Academy of Sciences (12). For that study, several econometric models were combined and the resulting impact multipliers used to obtain empirical estimates of the effects of pest control on soybeans and corn. Estimates were made, based on this report, of the effects on prices in the feed/livestock/meat economy of a 3-percent increase in corn and soybean production (table 3).

Table 3.—Estimated changes in prices due to a 3-percent increase in corn and soybean production in the United States

Item	Corn	Soybeans
<i>Percentage change</i>		
Prices received by farmers for corn	-3.1	---
Prices received by farmers for soybeans	---	-2.9
Soybean meal prices at wholesale	---	-1.5
Soybean oil prices at wholesale	---	-4.5
Price of fed cattle	-1.1	---
Retail price of beef	-.93	-.06
Farm price of pork	-1.3	-.24
Retail price of pork	-.72	-.15
Wholesale price of broiler chickens	-1.6	-.54
Retail price of chickens	-1.2	-.39
Retail price of eggs	-1.1	-.21
Retail price of margarine	---	-3.7
Retail price of shortening	---	-6.3
Retail price of salad oils	---	-4.3

Source: Based on estimates in National Academy of Science Report (12).

--- = not applicable.

Because the increase in production generally causes a corresponding decline in price, consumers are the major beneficiaries. To illustrate, assume the initial price of corn is \$2 per bushel and production is 5 billion bushels (figure). If production increases 3 percent, the price of corn drops approximately 3 percent (table 3). The research effort has increased production by shifting the supply curve from *S* to *S'*. Consumers gain *A* + *B* in consumer surplus from the increased production and lower price. The change in gross returns to producers is represented by the gain of *C* minus the loss of *A*. Note that we are comparing the change in consumer surplus with the change in gross returns to producers and not with "producers surplus." Quantitatively, the following effects have occurred: (1) the 3-percent increase in production means a gain of 0.15 billion bushels of corn, (2) the price drop of 3 percent means a decline from \$2 to \$1.94, (3) the gain in consumer surplus equals $A + B \approx 0.06 \times 5 \text{ billion bushels} + (0.5) (0.06) \times 0.15 \text{ billion bushels} = \304.5 million , (4) the change in gross returns to producers equals *C* - *A* which equals $\$1.94 \times 0.15 \text{ billion bushels} (\$291 \text{ million}) - \$300 \text{ million} = -\9 million . In summary, consumers gain \$304.5 million while producers lose \$9 million in gross returns.

As with corn, the farm price effect of the increased production of soybeans offsets the production effect, leaving gross farm income from soybeans virtually unchanged. The price effect is especially strong for soybean oil, and this spreads into the fats and oils

sector. The longrun effect on livestock is a half of 1 percent or less.

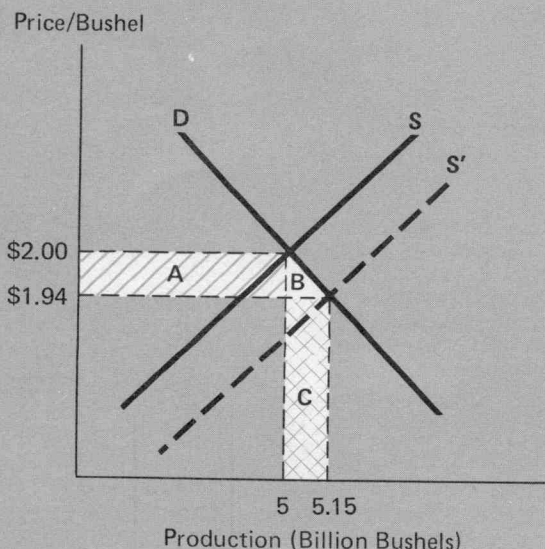
The analysis of corn and soybean research shows that there will likely be a high return with effects spreading throughout the feed/livestock/oils sectors. In the end, the consumers will be the major beneficiaries. However, to the extent that exports are more price responsive, the price effects will be smaller, and farmers will benefit more. There will also be an increase in foreign exchange earnings if export demand is elastic.

Conclusions

The application of benefit-cost analysis to future land grant universities' budget requests for agricultural research and extension will be a major task. However, the task seems feasible, particularly for crop and livestock research. A major advantage of this type of analysis is that it can be kept simple. The key in the analysis is the cooperation of the scientists; their estimates of potential outcomes are critical. Sensitivity analysis can be used to present policymakers with a range of returns under varying assumptions. If time permits, the results can be strengthened with estimates of the distribution of benefits between consumers and producers.

Based on the analysis of corn and soybean research, it appears that the land grant universities' research expenditures will bring a high return.

Impact of Research on
U.S. Corn Production



In Earlier Issues

Studies in land tenure... emphasized the opportunity for a young man to attain farm ownership through a series of steps under which he served an apprenticeship while acquiring the necessary capital. This series of steps, called the agricultural ladder, progressed from farm laborer to tenant to mortgaged-owner to full ownership...

In more recent years considerable interest has developed in father-son farm agreements which approximate a partnership to help the agricultural ladder to function. This type of tenure arrangement has its origin in three increasing trends: A greater capital requirement in farming, a longer period of life expectancy, and better opportunities for employment off the farm...

Recent trends in decentralization of industrial activity and increased professional services have offered farm youth more opportunities for employment off the farms. Farm youth who are not interested in farming as an occupation have found it easy to get started in other vocations.

"Father-Son Farm Agreements in Virginia," by W. L. Gibson, Jr. and F. D. Hansing. *AER*, Vol. I, No. 3, July 1949, p. 78.

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