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ESTIMATES OF POTENTIAL RETURNS FROM ADDED RESEARCH BUDGET FOR THE LAND GRANT UNIVERSITIES

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Investment in U.S. agricultural research is substantial and continues to expand. Numerous studies have shown that agricultural research expenditures have high rates of return. However, private investment in agricultural research is limited since private firms cannot capture enough of the benefits created by such investments. Thus, the public sector must do a large part of the 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.

With the growing competition for both federal and state budget funds, the Land Grant Universities have been called upon to provide projected rates of return or benefit cost analyses of their research and extension budget requests. In the past, however, evaluations of public research investments have concentrated on estimating past as opposed to future costs and benefits. To help respond to requests from the Office of Management and Budget and Congress for budget analysis, a committee was established in 1976 to begin to apply benefit-cost analysis to both

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the agricultural experiment stations and extension services budget requests.

This paper briefly reviews approaches that have been used to assess returns to U. S. agricultural research and explains the usefulness of benefit cost analysis in such evaluations. Benefit-cost analysis is applied to the Land Grant Universities federal budget requests for additional funds for corn and soybean research in the North Central region. Finally, the problems involved in applying a similar analysis to livestock and rural development research are discussed.

Review

The first major attempt at quantitative evaluation of agricultural research investments was conducted by T. W. Schultz [16]. He calculated the value of inputs saved in agriculture due to improved production techniques and compared this with the costs of research and development. His effort was followed by Griliches [5] who calculated the loss in consumer surplus that would occur if hybrid 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 where 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 the method that he and Griliches use (which he refers to as the index number approach) is to obtain 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 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 with the high point occurring after about six 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 was still the same as in 1910 and 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 then calculate a benefit/cost ratio.

Fischel [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 the most likely outcome as well as high and low outcomes that would be exceeded only one-third of the time and 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 with research as a separate independent variable to estimate the marginal products of research.

Another type of 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 the USDA published in 1966 the results of a study of agricultural and forestry research programs in the U.S. [22]. The study evaluated the strengths and weaknesses in the research program, identified future research problems, and recommended a level of public research for the 10 years. A major result of the study 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 then given a weight 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 carried out in Iowa to aid in the allocation of resources at the Iowa Experiment Station [9, 11]. This study was one of the first 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 given emphasis over the next five years. Various people scored the research program areas (RPA's) which were then ranked.

The majority of agricultural research evaluation studies have fallen 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 provide a ranking of alternative research projects or problem areas within an individual agricultural experiment station or nationally. Most of those studies in the first two categories are oriented toward the past while the third is oriented toward evaluating research for the present or future.

As a practical matter the federal government must evaluate experiment station requests for additional research funds annually. Can any of the techniques mentioned above play an important role in this evaluation process? The classification scheme developed in the USDA-SAES study aids in delineating where the funds might be used. Annual systematic <u>quantitative</u> estimation and comparison of benefits and costs are not made, however, and there is considerable skepticism about the possibilities for such analysis. Peterson [13] fears that widespread use of benefit-cost analysis could be very costly; some projects might require more resources to evaluate than the project budget. Williamson [24, p. 299] feels that the methodology is not adequate for ex ante estimation of research costs and benefits to be used as a basis for allocating research resources.

While problems of estimating benefits preclude the determination of an "optimal" allocation of research resources, quantitative cost benefit techniques may help policymakers improve their decisions. Certainly as a minimum, carefully calculated estimates of benefits can be compared with costs to determine which projects will likely yield positive returns.

Fedkew and Hjort [3] feel that cost benefit analysis can be a useful tool if sensitivity analysis is carried out and scientists are asked to provide an opinion on the probability of success for each project. The determination of a cost benefit ratio can be made relatively quickly even without a computer. Williamson [24] agrees but cautions that unless active support is obtained from the research scientists, reliability of estimates will be seriously impaired. Paulsen and Kaldor [11] emphasize the importance of keeping a benefit cost model simple so it does not overtax the time, resources, and patience of the administrative staff.

The literature suggests two important questions. (1) What information is required to estimate benefit cost ratios for future research expenditures? (2) How can this information be analyzed in a fairly simple model?

Corn and Soybean Research

To illustrate how benefit cost procedures can be applied to research, the Land Grant Universities' 1978 USDA budget requests for soybean and corn production research are analyzed. The analysis is for the North Central region where the largest increase in corn and soybean research funds is concentrated. The analysis is concerned only with the new research requests in the following research program areas (RPAs):

(1) RPAs 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 is used in the analysis (see Table 1). To calculate the benefits 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 will remain constant or the increase in quality will not lower livestock feeding costs, (4) a corn price of $2.00/bu. and soybean price of $4.75/bu., and (5) a probability of success of .8 for corn and .5 for soybeans.

Several of the above assumptions are probably conservative. The scientists estimated that production costs would decline as a result of the increased research. However, in the analysis only increases in yields are counted as benefits. The scientists also felt that the pro-

Table 1. Information Required for Estimating Returns for Public Research to Increase Corn and Soybean Production

	Crop	RPA	SY[a]	$/SY (000)	1975 Yield bu/acre	1975 Area (1000 acres)	% change in yield by the yr. 2000	Year avail.	Adoption Pattern (percent of total area) 1st	2nd	3rd	4th	5th
I	corn	207-9	2.5	77.1	88.9	54,722	2	1982	30	50	75	75	75
II	corn	307	3.0	72.3	88.9	54,722	2.25	1985	30	60	80	80	80
III	soybeans	207-9	1.5	69.6	31.1	33,557	1	1982	30	50	70	85	85
IV	soybeans	307	3.0	74.4	31.1	33,557	2	1985	40	70	90	95	95

[a] SY stands for scientist year which includes the cost of the scientist's salary as well as supporting facilities.

tein quantity and quality in corn should improve due to added research in RPA 307 which would lower feed costs. Finally the prices assumed for corn and soybeans were based on projections which assume no increase in exports over the period.

In contrast the estimated increases in yield may be high in light of past research productivity estimates [1]. However, two of the sets of benefit cost ratios were calculated assuming that the yield increases were only 50 percent of the yield estimates. The reduced yield estimates in conjunction with a lower probability of success made the yield increases more consistent with past trends.

As a check to see if the estimates are reasonable, all scientists from the North Central region working on corn in RPAs 207-209 and 307 are assumed to be just as productive as the new scientists. Under this assumption 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. Under the same assumption for soybeans, scientists from the North Central region in RPAs 207-209 and 307 would increase yields three bushels or not quite 10 percent in 25 years. Both outcomes seem highly probable in light of past productivity of agricultural research expenditures on cash grains [1].

Benefit Cost Estimates

The data can be incorporated in a simple framework to arrive at the benefit cost ratios (see Appendix 1). The ratios calculated for corn and soybeans are all extremely high (see Table 2 and 3). Corn in

Table 2. The Benefit Cost Ratios from New Production Research on Soybeans and Corn in the North Central Region

	Crop	RPA	Discounted Costs	Discounted Benefits	B/C
I	corn	207-209	1,612,338	221,702,680	137
II	corn	307	1,696,961	200,476,400	118
III	soybeans	207-209	873,298	38,920,000	45
IV	soybeans	307	1,746,249	69,265,943	40

Table 3. Sensitivity Analysis of the Benefits and Costs of New Production Research on Soybeans and Corn

	B/C under initial assumptions	B/C with longer lags	B/C with lower prob-abilities	B/C with lags and prob-abilities changed	B/C with $2.50 corn and $5.00 soybeans	B/C with 50% smaller yield increase	B/C with lags, prob-abilities and yield changed
I	137	117	86	73	172	69	37
II	118	102	74	64	148	59	32
III	45	38	27	24	47	22	12
IV	40	30	24	19	42	20	9

the North Central region is especially high because the yield increases occur over such a large acreage.

The cost benefit ratios are sensitive to changes in assumptions concerning the length of lags, probability of success, prices, and yields (Table 3). First, we extend the lag between the research expenditures and the availability of the results for adoption. The lag is increased from seven to ten years for RPA 307 and from four to six years for RPAs 207-209 which lowers the ratios as shown in Column 2. Second, the probability of success assumption is reduced from .8 to .5 for corn and from .5 to .3 for soybeans. Again, as displayed in Column 3 the ratios are lowered. 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 $5.00, respectively. These prices are closer to current prices and raise the ratios substantially as shown in Column 5. Fifth the yield response is reduced by 50 percent and again the ratios are lowered as shown in Column 6.[1/] Finally, the length of lag is increased, the probability of success reduced and the yield response lowered by 50 percent. These changes lower the ratios substantially. Yet the ratios remain high indicating research has a high payoff over a wide range of assumptions.

Distribution of Benefits

One should be cautioned that while these ratios are high, any

[1/] Note that a 50 percent reduction in the acreage effected by the new research would have the same impact as the yield reduction.

technological change resulting from research will likely have some unforeseen consequences. The benefit cost ratios say nothing about the distribution of those 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. One reason low prices were assumed for corn and soybeans in the previous example was to reflect the price effect of increased production. For ease of calculation, the low price was assumed constant instead of continuously declining from 2.50 to 2.00.

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 estimates published in a recent report by the National Academy of Sciences are used [12]. For that study, several economic models were combined to obtain empirical estimates of the effects of pest control on soybeans and corn. Estimates are 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 (see Table 4). These figures are not intended to be precise calculations, but rather approximations to illustrate the types of changes that would result from an increase in corn and soybean production due to additional research.

The price effect on corn approximately offsets the increase in production leaving gross farm income from corn almost unchanged. Prices of livestock all decline by less than 2 percent and the effect is less at the retail level than at the farm level.

As with corn, the price effect of the increased production of soybeans almost 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 long run effects on livestock is a half of 1 percent or less.

In summary, 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 likely be the major beneficiaries. However, to the extent that exports are price responsive, the price effects will be smaller, and the farmers will benefit more. There will also be an increase in foreign exchange earnings if export demand is elastic.

Livestock

The benefit cost framework applied to corn and soybeans can

Table 4. Estimated Changes in Prices Due to a 3% Increase in Corn and Soybean Production for the Entire Country.[a]

Item	Corn	Soybeans
	% change	
Prices received by farmers	-3.1	-2.9
Soybean meal prices at wholesale	---	-1.5
Soybean oil prices at wholesale	---	-4.5
Price of feed 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

a/ Source: Based on estimates in [12].

be generalized to many cash grain and other crops. It can also be useful for analyzing livestock research although the types of benefits may be more difficult to quantify.

The benefits from beef cattle research might be measured in terms of increased reproductive efficiency, reduced cow maintenance costs, lower costs per pound of gain or improved meat quality. A good starting point would be to focus on the costs per pound of gain. Swine research benefits would be quite similar with increased reproductive efficiency and lower costs per pound of gain being important measures of benefits.

For dairy cattle the measurement problems will be a little different. The most important output is milk rather than meat. Thus milk production per cow would be the primary measure. Reproductive efficiency and percent butterfat should also be considered.

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 reproductive efficiency and reduce the cost per pound of meat or milk.

Rural Development

Still more difficult to evaluate is the rural development research and extension efforts. Title V of the Rural Development Act of 1972 provides special funding for research and extension programs for rural development. Since these programs have been in operation for several years it is now realistic to consider some form of evaluation. However, if reasonable lag is assumed, one would not expect these programs to have had much impact, yet, in terms of increased income or employment.

The primary objectives of the Rural Development Act are to: increase employment and income opportunities, improve essential community services and facilities, improve quality of life, improve housing and enhance those social processes necessary to achieve these objectives. Several of these objectives will be easier to evaluate than others. Probably the most difficult objectives to evaluate are the improvement in quality of life, which is subject to many interpretations, and the enhancing of social processes.

The research efforts under the Rural Development Act are of two general types. One is to provide better information to improve allocation decisions. A second is to construct alternative plans or programs to deal with particular community problems. The latter includes an analyses of the possible consequences of alternative courses of action.

In Minnesota both types of research are being done. One major emphasis has been on providing better information on land and related resources to county and township officials. The objective is to improve local decisions concerning land use. The other major emphasis has been to analyze Region 6E's transportation systems. Alternative restrictions on the transportation systems are being analyzed to determine the impact on Region 6E's economy.

Will this research and extension lead to better decisions that result in improved transportation and land-use? To evaluate impacts particularly in land-use, cost effectiveness analysis is probably more feasible than cost-benefit analysis. It is much more difficult to put a dollar value on improved land-use regulations then on an additional bushel of corn. On the other hand, if the improved transportation systems leads to a measurable increase in jobs and incomes, benefits could be valued in dollar terms. Still measuring benefits on a regional basis is a risky proposition because of the possible loss of jobs and incomes in other regions. Thus, in general it is more realistic to expect cost-effective analysis to be the primary means of evaluating rural development research and extension.

To apply cost-effectiveness analysis to future budget requests for rural development will involve three kinds of information: (1) a listing of specific research and extension objectives, (2) a cost breakdown by objectives (how much will be spent to meet each objective), and (3) a display of projected outcomes in dollar terms, if possible, or in physical terms. Finally an attempt should be made to compare the cost of these projected outcomes with alternative methods of obtaining the same results.

The objectives and costs information should come from the budget proposals. The possible outcomes could be obtained from social scientists working on similar problems. Alternative methods might also be obtained from social scientists. However, in many cases, this information will be location specific. Thus, the evaluation will involve numerous outcomes.

Conclusion

In conclusion, the analysis of future Land Grant Universities budget requests for agricultural research and extension will be a major task. However, the task seems feasible particularly for crops and livestock research. On the other hand, rural development research results are more difficult to quantify. It is a much more heterogenous product then the output of crops and livestock research.

Based on the analysis done of soybean and corn research, it appears that Land Grant Universities have a high return product. Analysis rather than being an odious task, may be an important element for helping focus and increase agricultural research and extension funding. Evaluation of returns from past agricultural research clearly supports this idea. However, the key in the analysis of future returns is the cooperation of the scientists and social scientists. Their estimates of potential outcomes is critical.

Appendix 1

Example of How Information was Employed to Obtain a Benefit/Cost Ratio

North Central Region, Corn, RPA 307

Year	Bu/acre increase	X	Probability of Success	Increase in production taking into account the adoption rate	X	price/bu		Nondiscounted benefits	X	$\frac{1}{(1+r)^i}$
								(1000 dollars)		
1978	0			0						
.	.			.						
.	.			.						
.	.			.						
1985	.125	X	.8 = .1	(5472 x .3) = 1642	X	2	=	3283	X	.466507
1986	.25	X	.8 = .2	(5472 x .3)+(5472 x .6) = 4925	X	2	=	9850	X	.424098
.			.	4925 + (.8 x 5472) = 9303	X	2	=	18606	X	.385543
.	.		.	4925 + (.8 x 10944) = 13680	X	2	=	27360	X	.350494
.	.		.	.		.		.		.
2000	2.00	X	.8 = 1.6	.		.		132,421	X	.111678

Lags: Benefits begin 1985, benefits end 2000.
Nondiscounted costs = 3 SY's x 72,300/SY = 216,900/year

Note: One could wait and not multiply by the probability of success or the price/bu until after calculating $\sum_{i=8}^{23} \frac{B_i}{(1+r)^i}$. The result would be the same and would facilitate sensitivity analysis.

$$\sum_{i=8}^{23} \frac{B_i}{(1+r)^i} = 200,476 \times 1000$$

$$\sum_{i=1}^{16} \frac{C_i}{(1+r)^i} = 216,900 \times 7.823709 = 1,696,961$$

$$B/C = 118.14$$

Appendix 2

Table A. Nondiscounted Costs and Benefits for New Soybean and Corn Research

	I		II		III		IV	
Year	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits
1978	192750	0	216900	0	104400	0	223200	0
1979	192750	0	216900	0	104400	0	223200	0
1980	192750	0	216900	0	104400	0	223200	0
1981	192750	0	216900	0	104400	0	223200	0
1982	192750	2430	216900	0	104400	392	223200	0
1983	192750	6478	216900	0	104400	1045	223200	0
1984	192750	12551	216900	0	104400	1959	223200	0
1985	192750	18625	216900	3283	104400	3070	223200	1275
1986	192750	24699	216900	4850	104400	4182	223200	3506
1987	192750	30773	216900	18606	104400	5293	223200	6307
1988	192750	36847	216900	27360	104400	6404	223200	9402
1989	192750	42921	216900	36116	104400	7515	223200	12430
1990	192750	48995	216900	44870	104400	8626	223200	15458
1991	192750	55069	216900	53626	104400	9737	223200	18486
1992	192750	61143	216900	62381	104400	10848	223200	21514
1993	192750	67217	216900	71136	104400	11959	223200	24542
1994	192750	73291	0	79891	104400	13070	0	27570
1995	192750	79365	0	88646	104400	14181	0	30598
1996	192750	85439	0	97401	104400	15292	0	33626
1997	0	91513	0	106156	0	16403	0	36654
1998	0	97587	0	114911	0	17514	0	39682
1999	0	103661	0	123666	0	18625	0	42710
2000	0	109735	0	132421	0	19736	0	45738

Appendix 3

Information needs to be collected from physical scientists for any benefits costs analysis of additional research to be successful. Listed below are the types of questions which need to be asked of the physical scientists at the relevant agricultural experiment station.

(1) If you were given an additional x% of research funding each year for the next Y years, describe the type of research that would be carried out under each RPA and crop.

(2) What is the expected increase in yield or reduction in total costs resulting from the additional funding for each RPA and crop?

(3) What in your opinion is a very conservative estimate of the increase in yield or reduction in total costs? a liberal estimate?

(4) What in your opinion is the probability of success for each RPA and crop?

(5) What will be the most likely lag between research expenditures and availability of results to the farmers for each RPA and crop?

(6) Describe the pattern of adoption by farmers once the results are available by RPA and crop (i.e., what percentage of the farmers will use the results the first year, what percent the second year, third year, fourth year, and so on?).

(7) How widespread will the results be? (state, regional, national?)

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