Evaluating Agricultural Research and Productivity

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EVALUATING SOCIAL SCIENCE RESEARCH IN AGRICULTURE

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Federal financial support for agricultural research has stagnated in real terms for the past 20 years while pressures to justify research budgets have increased. Partly in response to these pressures, agricultural economists have conducted a variety of studies to evaluate the public agricultural research investment. Several of these evaluation efforts have examined aggregate agricultural research and extension; others have assessed particular technologies. Few studies, however, have attempted to quantitatively measure impacts of social science research (SSR) including agricultural economics research (AER). The need to evaluate SSR arises from two primary sources. First, as budgets tighten, there are increasing requests from public decision makers to provide evidence on the value of that research including AER. Second, an introspective look at the value of SSR can provide guidance for future research directions.

In an invited address to the American Agricultural Economics Association at Cornell in 1984, Ruttan argued that social scientists have only begun to conceptualize the contribution of knowledge in social sciences. He hypothesized that the demand for knowledge in economics and in other social sciences is derived primarily from the demand for institutional change and improvements in institutional performance. Interestingly, the fact that economists have devoted so much time to evaluating agricultural research over the past few years in response to the demands of administrators and policy makers responsible for institutional performance would seem to support that hypothesis. Ruttan cited other examples. He did not, however, provide quantitative estimates of the benefits of SSR although he noted that the lack of economic knowledge has at times imposed very heavy costs on American farmers and the American Economy (Ruttan, p. 557).

The objective of the current paper is to suggest not only conceptual but empirical means for assessing the value of SSR. The focus is on empirical issues and procedures because of both the need for and the relative lack of quantitative evaluation of SSR. Furthermore, the paper concentrates on AER due to its relative importance, in terms of funding, within agricultural SSR. In the first section, the importance of AER relative to total agricultural, forestry, and home economics research is highlighted. This is followed by a discussion of the problems and conceptual issues inherent in evaluating AER. Possible empirical procedures are described and an application is presented which utilizes an approach for valuing information. Finally, implications for future evaluations of agricultural economics research are discussed.

MAGNITUDE OF AGRICULTURAL ECONOMICS RESEARCH IN THE U.S.

Prior to considering methods for evaluating AER, it is useful to gain a perspective on its magnitude. The USDA Current Research Information System (CRIS) publishes research expenditure data by Commodity Group and Research Problem Area (RPA). The most recently published CRIS data were examined and an effort made to sort out those RPS's containing primarily agricultural economic research. Out of the total 100 RPA's in the CRIS system, 21 appear to contain primarily AER components and are listed in Table 1. In 1985, out of 1,928 million dollars spent on research by the State Agricultural Experiment Stations, USDA, Forestry Schools, and other cooperating institutions, approximately 125.5 million dollars, or 6.5% was spent on these "agricultural economics" RPA's. Figures for 1981 for the same RPA categories reveal that 7.0% of total expenditures was spent on AER. This indicates that from 1981 to 1984 AER slipped marginally in funding vis a vis other types of agricultural research in the aggregate. Substantial funding declines occurred in the rural development RPA's (803, 804, 806, 807). These figures must be used with caution because some of the RPA's listed contain non-AER components. Furthermore, several RPA's not listed, particularly in the soil and water areas, contain substantial AER. Nonetheless, these figures provide a rough indication of the magnitude of AER in relation to total agricultural research performed at

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Table 1: Expenditures on Major Agricultural Economics Research Categories in 1985 Classified by Research Problem Area (RPA), Total USDA-SAES-Forestry Schools - Other Cooperating Institutions.

RPA	Title	No. of Projects	Scientist Years	Total Funds($)
104	Alternative Uses of Land	191	115.4	8,614,078
108	Econ. and Legal Prob. of Water Management	56	24.2	2,599,623
114	Rsch. on Mgt. Research	50	51.3	6,985,885
316	Farm Business Mgt.	173	75.1	7,222,637
503	Marketing Eff. of Agr. Production and Inputs	201	70.9	7,964,031
506	Supply, Demand and Price Analysis	244	141.1	14,797,322
507	Competitive Interrelationships in Agriculture	67	21.0	2,448,241
508	Domestic Market Development	39	6.8	1,263,645
509	Performance of Marketing Systems	188	96.7	10,504,291
510	Group Actions and Market Power	32	11.6	1,469,326
511	Improvement in Agr. Statistics	36	8.6	1,792,389
601	Foreign Market Development	150	154.3	15,380,055
602	Evaluation of Foreign Food Aid Programs	5	.5	52,528
703	Food Consumption Habits	152	42.3	11,313,127
803	Rural Poverty	30	7.5	768,964
804	Improve Econ. Potential of Rural People	96	34.4	3,939,467
806	Adjustment of Change	197	54.1	2,851,413
807	Structural Changes in Agriculture	205	101.2	10,258,112
808	Govt. Programs to Balance Farm Output and Demand	72	37.8	4,211,918
907	Improve Income Opportunities in Rural Communities	103	46.9	4,812,836
908	Rural Institutional Improvement	176	58.7	6,266,950
	Subtotal, Agricultural Economics Research Problem Areas			125,516,838
	Total, All Research Problem Areas			1,927,991,221

Source: USDA, CSRS Inventory or Agricultural Research, FY1985, Vol. II, 1986, pp. 2-3.

public institutions. While AER is not large in relation to total agricultural research, it still represents a sizable public investment.

CONCEPTUAL PROBLEMS AND ISSUES

The list of RPA's in Table 1 suggests some of the difficulties inherent in AER evaluation. Agricultural economics research is diverse, directed at various goals, and produces a variety of hard to measure outputs. Some research projects are concerned with increasing or stabilizing aggregate income while others are directed toward facilitating a more equitable income distribution or improving health and safety. Some are aimed at multiple goals.

Many of the problems of AER evaluation relate to measurement of research output. A common thread running through most AER is that the output is information. Biological, physical, and mechanical research also produces information, but in those cases the information is eventually imbedded in new inputs or products or can be identified in a more tangible way. In the case of AER we do not have such imbedding. To the extent that it does occur, the information is imbedded in new policies and institutions. As noted above, Ruttan has suggested that the demand for knowledge in economics and other social sciences is derived primarily from the demand for institutional change or increased efficiency in institutional performance. The value of AER therefore results from reduction in the cost of institutional innovation, analogous to the reduction in cost of technical innovation resulting from new biological, physical, and mechanical technologies. In fact, as Ruttan, Bonnen, and Schultz have each noted, the demand for institutional change itself often results when new biological and physical technologies are introduced, resulting in disequilibria in factor and product markets.

The conceptualization of AER producing information which reduces the cost of institutional change is useful, but other difficulties remain in attempting to measure the value of AER. One is the problem of determining causality of change which occurs following AER. One can link yield changes to plant breeding research easier than he can link change in farmer behavior or institutions to AER. Even if institutional change occurs following a piece of research which suggested the change, one can never be certain that the change would not have been made anyway for political or other reasons. Related to this is the fact that information is available to economic agents from sources other than public research and extension.

Occasionally the linkage between research and institutional change can be made confidently. For example, Adams documented the role of AER which resulted in the creation of the IMF Cereal Import Facility. That study also illustrates, however, the common phenomenon of multiple research studies contributing pieces of information which eventually add up to a useful whole. Often it is difficult to account for the various pieces in determining the real research cost.

An issue related to the multiple researcher case is the problem of placing value on basic as well as applied research. An applied study which utilizes a modeling tool which itself is the product of basic statistical or econometric research creates difficulties in measuring research costs. There are cases where one can argue that the marginal value and marginal cost of the applied study represents the relevant benefit and cost, but clearly there is a complementarity between applied and basic research which must be accounted for lest the value of basic research continually be undervalued. Of course this is true for non-agricultural economics as well as agricultural economics research.

The complementarity issues arises again with respect to the interaction between research and extension, and this too is a familiar problem with non-agricultural economics research. An additional complementarity problem is described by Bonnen who notes the important interaction among human capital, technology, and institutions. He says that it is a major intellectual misunderstanding to attribute the entire increment of an increase in productivity to any one of these three complementary factors (Bonnen, p. 959).

Timing is another critical element affecting the value of AER. Adams mentions the importance of timing in determining the usefulness of the AER behind the creation of the IMF Cereal Import Facility. One could argue that the forces which create the demand for institutional change will improve the likelihood of the information produced by AER being timely, at least for applied research. Another timing related issue is the adoption rate of AER information and its implications for distribution of research benefits. Just as the benefits of new biological and physical technologies accrue to early adopters, so too with AER. Those firms able to obtain information on a more timely basis may gain a competitive advantage over other firms creating an information treadmill effect with implications for structural change in agriculture.

When one takes the perspective that the output of AER is information, it is useful to consider what types of information are produced and who the users are. The major types of information provided by AER can be classified into three groups: (1) management and price information used primarily by producers, consumers, and policy makers, (2) institutional information used primarily by administrators and policy makers, and (3) disciplinary information (mainly related to economics, statistics, and operations research) used by other researchers. Regardless of who the initial users are, the ultimate beneficiaries tend to be individual economic agents, typically producers and consumers. As noted above, AER projects can impact on various goals (e.g., growth, equity, security), but many if not most projects have some effects which can be measured or at least conceptualized in terms of having an economic value. Let's examine briefly how this value arises.

Management and Price Information

Many agricultural economics research projects provide management or price information to facilitate attainment of technical or allocative efficiency. Technical efficiency gains can result from improved timing of input usage, fuller exploration of the complementary relationships among inputs, etc. Allocative efficiency gains result from the potential to provide producers with improved knowledge of the most profitable or utility maximizing contributions of inputs and outputs given the technology. Management and price information on consumption of food and fiber similarly can increase the efficiency of household production and subsequent utility. The value of management and price information is derived from the reduction in uncertainty facing economic agents. Reduced uncertainty results in efficiency gains and to the extent that these agents are risk adverse, management and price information results in additional utility gains through lower income variability.

Institutional Information

Information produced by AER often is used by policy makers or groups of individuals who redefine public policies, property rights, or in more general terms, institutions and then these changes in turn lead to actions on the part of individual economic agents. The term institution can be defined as the set of behavioral rules that govern a particular pattern of actions and relationships (Ruttan, 1978). Changes in farm programs, environmental regulations, or rural development programs can be considered institutional change. Frequently, new institutional information affects allocative and technical efficiency. It perhaps affects equity and security more often than does management and price information.

Disciplinary Information

Disciplinary information can be thought of as being produced by basic research in agricultural economics. An improved econometric technique or an improved procedure for measuring economic welfare gains unrelated to a specific public policy provides information which more applied researchers can utilize. Just as the demand for institutional change is derived in part from new biological and physical technologies, the demand for disciplinary research is derived from the need for theories and tools to conduct price and management (structural) and institutional research. Because this demand is so diffuse, however, it is virtually impossible to isolate the benefits of specific types of disciplinary research.

EMPIRICAL PROCEDURES FOR EVALUATING AER

The output of AER is information. Two approaches commonly used to empirically assess the value of information have been the net social benefits approach and the decision theoretic approach. The net social benefits (consumer-producer surplus) approach has been applied by Hayami and Peterson, Bullock; Freebairn (1976, a,b); Bradford and Kelegian (1977, 1978); Thabet, Ray and Bullock; and Norton and Schuh to evaluate net benefits of more accurate outlook and price information.

The benefits of research leading to improved outlook and price information are illustrated in its simplest form in Figure 1a.

Figure 1a. Welfare effects when price is overestimated.

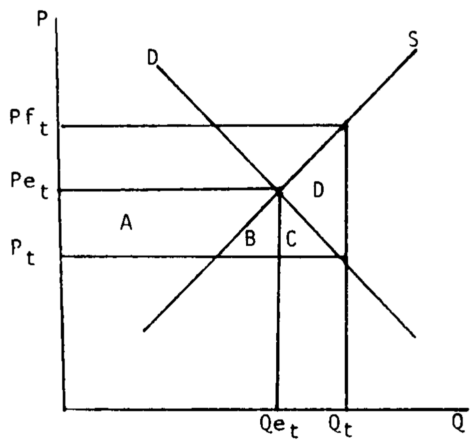
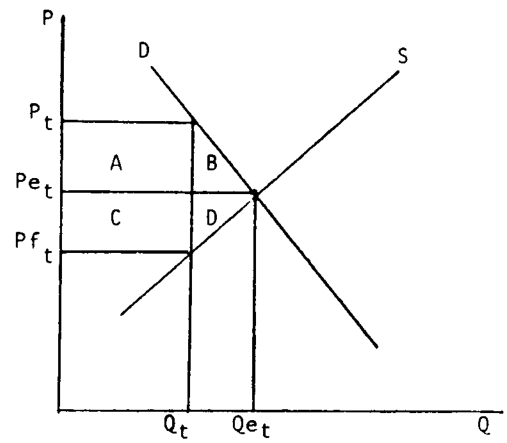


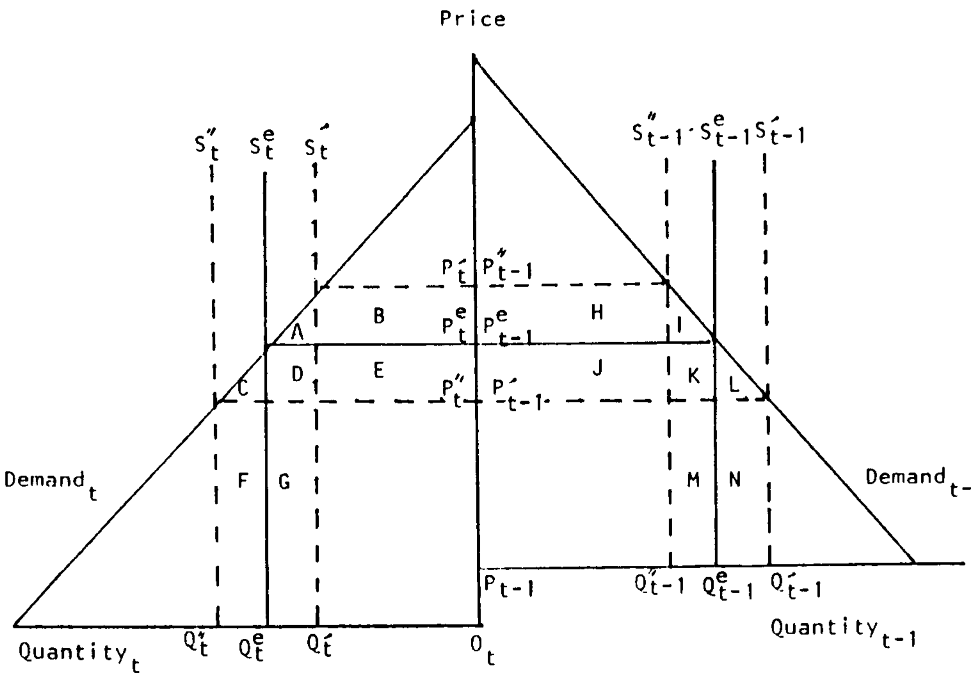
Figure 1b. Welfare effects when price is underestimated.



Assume producers estimate the price of the commodity to be Pf_t which is above the equilibrium price Pe_t. In this case they produce a quantity of Q_t which is larger than the equilibrium quantity Qe_t. The resulting price is P_t and resulting change in net social benefit is A + B +C - (A + B + C + D) = -D. Likewise when producers underestimate price (Figure 1b), the change in net social surplus is -(A + B) + (A - D) = - (B + D). Bearing in mind the well known limitations of consumer-producer surplus measures, if AER efforts lead to price forecasts which are closer to Pe_t, then net social losses will be reduced. Most of the studies noted above separate the cases where production as opposed to only inventory adjustments can occur. Thabet, Ray, and Bullock also consider cross-commodity effects of outlook information. This model has been employed by Freebairn (1976, a,b) who also derives expressions for expected welfare effects on producers, consumers, and society of producers using perfect foresight prices relative to rational (but inaccurate) forecast prices in supply decision making.[1] Freebairn (1976,b) and Thabet, Ray, and Bullock extend the model to capture cross-commodity effects from inventory behavior.

The model is Figure 1 abstracts from inventory behavior. Potential gains and losses also can be realized from research which results in more accurate outlook and price information which in turn leads to intertemporal inventory changes. This is illustrated with a two period model in Figure 2. In equilibrium, the price in period two (Pe_t) equals the price in period one (Pe_{t-1}) plus the cost of storage. If too much were sold in period one (Q'_{t-1}), the observed period one price would drop to P'_{t-1} and the amount available for sale in period two (Q'_t) would result in the period two price, P'_t. Consumers would gain J + K + L in period one and lose A + B in period two. The change in producer surplus would be N - J - K in period one and B - D - G in period two. The net economic surplus change would be L + N - A - D - G. Likewise if too little were sold in period on (Q''_{t-1}) and too much in period two (Q''_t), the period one price would be P''_{t-1}, the period two price, P''_t, consumers would lose H + I in period one and gain C + D + E in period two, the change in producers surplus would be H - K - M in period one and F - D - E in period two, and the net change in producer surplus would be H - K - M in period one and F - D - E in period two, and the net change in economic surplus would be C + r' - I - K - M. This basis model is similar to those considered by Hayami and Peterson, Bullock, and Bradford and Kelegian (1977, 1978), and Norton and Schuh. Thabet, Ray and Bullock extend the models in Figures 1 and 2 by allowing for both production and inventory adjustment as well as multiple commodities.

Figure 2



Freebairn (1976,b) evaluates the welfare effects of more accurate forecast prices in terms of more precise knowledge about factors causing shifts in the demand for and supply of agricultural commodities. He assumes that price expectations are formed rationally in the sense described by Muth.[2] He assumes that supply and demand curves have known parameters on the price variable but random error terms. The intercept terms reflect the effects of all other variables on the demand and supply of the commodity. Cyert and DeGroot argue that this is a black box concept of a rational expectation and that a process has to be developed if the rational expectations hypothesis is to be anything other than a religious belief. They assume Bayesian learning in describing the process by which expectations, once formed, lead to an equilibrium. Learning takes place in the market and has the effect of continually modifying the prior probability distribution with which the firms start. Prior distributions are assigned to the unknown values of all parameters wherever they appear in the model (including the parameters on the price variables). Cyert and DeGroot show that it is in the Bayesian framework that the rational expectations approach finds its natural setting.

Bradford and Kelegian (1977, 1978) and Norton and Schuh apply Bayesian decision theory to evaluate outlook and price information. In effect they argue that the rational expected price is arrived at through Bayesian learning, but that learning results not only from observing market behavior but from public outlook and price information. This information not only causes speculative inventory holders to revise their prior probability distribution, but affects the commodity price distribution. These changes are evaluated using the net social surplus approach described previously. The value of information is the difference between maximum utility with and without outlook information. Bradford and Kelegian (1978) implement their model for the case of wheat crop forecasting in the United States. Norton and Schuh consider the case of soybean outlook information provided each fall by agricultural economists at the University of Minnesota.

One advantage of the decision theory approach is that it explicitly considers the fact that the value of information is an outgrowth of the economic theory of uncertainty. As Hirschleifer points out, uncertainty is summarized by the dispersion of individuals' subjective probability distributions over possible states of the world. Information consists of events tending to change these probability distributions.[3] The major problem with using the decision theory approach is in the estimation of subjective probabilities in the prior and posterior situation. Norton and Schuh assumed that subjective priors were based on historical probabilities of price movements for the previous 15 years. Conditional probabilities were determined by looking at past outlook projections and actual states of nature which occurred. These probabilities were then used to calculate the posterior probabilities using Bayes formula. Another problem is that the appropriate utility function must be determined unless a linear utility function is assumed so that maximizing expected profits is equivalent to maximizing expected utility (Eidman, Carter, and Dean). This is in fact what Bradford and Kelegian (1978) and Norton and Schuh assume. A third problem is that one can argue with the hypothesis that economic agents behave as though their priors are updated according to Bayes theorem.

The net social benefits and decision theoretic approaches are feasible for evaluating certain types of agricultural economic research projects, especially when profit maximizing or risk neutral behavior is assumed. Attempts to evaluate broader classes of research output such as the management-price, institutional, or disciplinary classes of information will likely require alternative approaches, especially if one considered that agents are risk adverse.

Antonovitz and Roe (1982, 1985) suggest alternative measures for valuing information under price uncertainty while Roe and Nygaard present a measure for the value of information when the parameters of the underlying technology are not known with certainty by the producers. These studies rely on the notions that producers allocate resources based on their subjective estimates of prices and parameters of the underlying technology, and that these estimates are not entirely accurate. However, rather than assuming that producers behave as though their priors are updated by Bayes Theorem, they suggest means for valuing information based on "subjective" and "actual" or "more informed" production and/or profit functions. They provide one ex post and two ex ante measures of the value of information. The ex post measure is determined by comparing profit realized in the subjective state with profit realized in the state of perfect information. In the two ex ante cases, the actual output price is not assumed to be known, but rather decisions made in the subjective state are compared with those made in a more informed state. As with the decision theory approach, value of information generated for the individual firm then can be translated into a measure of the value of information to society using the economic surplus approach.

The procedures suggested by Antonovitz and Roe appear to provide a means for evaluating the broad program areas of farm marketing and management research and extension. An example is presented below to illustrate a possible method for estimating returns to agricultural economics research and extension aimed at improving allocative efficiency.

EMPIRICAL EXAMPLE OF EVALUATING AER

Assume in our example that producers exhibit profit maximizing risk neutral behavior. Profit is $\pi = Pq - C(q)$ where P is stochastic input price, q is quantity, and C(q) is the cost function. Expected profits $\pi^e = p^e q^o - C(q^o)$ where p^e equals expected price when input decisions are made, and q^o is the quantity produced. When q^o is sold at the realized price p^r, realized profit $\pi^r = p^r q^o - C(q^o)$. Because P is stochastic, p^r may not equal p^e. Denote the optimal output choice under perfect information as q^t. Profits under perfect information $= \pi^t = p^r q^t - C(q^t)$. In this situation, Antonovitz and Roe point out that one measure of the value of information is defined to be the difference between profits earned in the state of perfect information, π^t, and profits earned in the realized state π^r. The value of information (also allocative error) which can be denoted by VI is given by:

$$VI = \pi^t - \pi^r = (p^r q^t - C(q^t)) - (p^r q^o - C(q^o))$$

The usefulness of this concept becomes apparent when one considers that π^r and q^o are observable, π^t can be estimated as shown below, and then the relationship between $\pi^t - \pi^r$ and certain types of agricultural economics research can be estimated. $\pi^t - \pi^r$ represents a measure of potential allocative efficiency gains.

Profit functions arise naturally out of duality theory which implies that properties of production technology and choice can be fully described by expected profit, input demand and output supply functions. Assume firms choose a (1xm) vector of planned output levels q^o, and a (1xn) vector in input flows, x^o, in order to maximize expected profit, π^e, subject to a (1xp) vector of fixed factors, Z, a (1xm) vector of expected output prices, p^e, a (1xn) vector of input prices, R, and a production technology that satisfies the usual neoclassical properties. The indirect profit function relates maximized expected profit π to P, R, and Z:

$$(1) \quad \pi = \pi(P,R,Z),$$

and by Hotelling's lemma, the output supply and input demand functions are as follows:

$$(2) \quad \frac{d\pi}{dP_i} = q_i = q_i(P,R,Z) \quad i = 1 \ldots m,$$

$$(3) \quad \frac{d\pi}{dR_h} = x_h = -x_h(P,R,Z) \quad h = 1 \ldots n.$$

Fixed factors, Z, include fixed inputs such as land and farmers' education as well as public policy variables such as agricultural research and extension. Note that the aggregate impact of all agricultural research on output of a particular commodity q_i can be obtained as $\frac{dq_i}{dz_j}$ where Z_j is measured as agricultural research expenditures (See Huffman and Evenson for an example).

The impact of AER can be derived by estimating the system of equations (1)-(3) using expected prices and then using the parameters so estimated along with actual prices and fixed factors to determine optimal profits, π^t. The following relationship can then be estimated:

$$(4) \quad \pi^t - \pi^r = f(Ex, AER, ED, CV)$$

where Ex is extension expenditures on business management and marketing; AER is public expenditures on farm management, marketing efficiency, and price analysis research; ED is education; and CV is a coefficient of variation of output prices.

Econometric Models

A set of 10 output supply and input demand equations were estimated jointly using data for 42 U.S. states pooled over agricultural census years 1978 and 1982. The normalized quadratic flexible functional form was employed for the profit function. It imposes homogeneity in prices and results in output supply and input demand functions which are linear in normalized prices. The normalized quadratic profit function can be represented as:

(5)

$$\pi = a_o + \sum_{i=1}^{m} a_i P_i + \frac{1}{2}\sum_{i=1}^{m} b_i P_i^2 + \sum_{h=1}^{n} c_h R_h + \frac{1}{2}\sum_{h=1}^{n} d_h R_h^2 + \frac{1}{2}\sum_{i=1}^{m}\sum_{h=1}^{n} e_{ih} P_i R_h + \sum_{j=1}^{p} f_j Z_j + \sum_{j=1}^{p}\sum_{k=1}^{p} g_{jk} Z_j Z_k$$

$$+ \sum_{i=1}^{m}\sum_{j=1}^{p} d_{ij} P_i z_j + \sum_{h=1}^{n}\sum_{j=1}^{p} V_{hj} R_h Z_j$$

where a,b's, c's, d's, e's, f's g's, l's, and v's are the unknown parameters of the profit function. The output supply and input demand functions can be represented as in equations (6) and (7) respectively:

$$(6) \quad q_i = a_i + \sum_{i=1}^{m} b_i P_i + \sum_{h=1}^{n} e_{ih} R_h + \sum_{j=1}^{p} d_{ij} Z_j$$

$$(7) \quad X_h = C_h + \sum_{h=1}^{n} d_h R_h + \sum_{i=1}^{m} e_{ih} P_i + \sum_{j=1}^{p} V_{hj} Z_j$$

The above model is normalized on one of the prices and the equation (output supply or input demand) associated with that price is obtained residually from the parameters of the remaining equations following estimation. Cross equation symmetry restrictions, $e_{ih} = e_{hi}$, are imposed to reduce the number of unknown parameters to be estimated. The equations represented by (5) and (6) were estimated jointly using Zellner's seemingly unrelated regression procedure to increase efficiency. Equation (4) was then estimated in linear form using OLS.

Variables and Data

Farmers' output and input choices by state were condensed into seven per farm output indexes (small grains, other major grains and potatoes, hay, other crops, milk, poultry, and other livestock)[4] and four variable inputs (commercial fertilizer, labor, petroleum products, and feed). Inputs assumed to be fixed or exogenous within each observation period include land, deviation from annual average July rainfall, the stock of breeding livestock, other capital items, agricultural research, agricultural extension, and education. We assume that other miscellaneous inputs are not contemporaneously related to prices or fixed inputs so their exclusion will not bias the estimated coefficients. These fixed factors together with normalized output and variable input prices are assumed to explain farmers' output and input choices.

The data collection and subsequent transformation to construct output and input quantities and prices required a sizable effort. Quantity and price data on all major agricultural commodities for each state were collected. The output quantity indexes were constructed with quantity data collected from the Census of Agriculture and price data collected from Agricultural Prices. Expected output prices used in the output price index variables were either (1) futures market prices for harvest contracts observed at planting time adjusted by the basis between each state and the state where the futures market is located, or (2) for those commodities for which no future markets exist, one year lagged state average prices received by farmers. The expected milk price is the numeraire price in the model and all output and input prices are divided by it.

Farm labor includes operator (adjusted for age and days worked off the farm) and hired and contract labor and was derived from Census of Agriculture data. The wage rate for farm labor is the state average wage rate for hired labor (Agricultural Statistics). The petroleum (fuel) quantity and price variables are indexes of gas, diesel, and L.P. gas derived from data in the Census of Agriculture and Agricultural Prices. The quantity of feed variable was from the Census of Agriculture and the fertilizer quantity from Agricultural Prices. The prices of fertilizer and feed were obtained by dividing the values of commercial fertilizer and feed from the Census by their respective quantities.

The land variable is a quality (price) weighted index with the weights obtained from Davis. Capital items include the service flow from machinery and custom services based on

Census of Agriculture data, and the breeding stock variable is a weighted index of cows (1), sows (.4), and ewes (.2), also from the census. Rainfall data were obtained from Weiss et al. Agricultural extension is measured as the one year lagged value of each state's agricultural extension funds. These data were obtained from the Extension Service, USDA in Washington. Agricultural research is measured as a 12-year quadratic distributed lag of research expenditures with the data obtained from the Inventory of Agricultural Research. Education is based on a variable constructed by Davis. An intercept dummy on peanuts and a slope dummy on peanut price was included in the other grain's equation to account for differences arising from the small number of states producing peanuts. Similar dummies were included for the Southern States and "other crop" price because the mix of "other crops" differed substantially between Northern and Southern states.

The extension variable in equation (4) is current expenditures on business management and agricultural marketing extension. Data were obtained from the Extension Service, USDA in Washington. Agricultural economics research is measured as current expenditures on business management, marketing, and supply and prices analysis lagged one year. These data were obtained from RPA's 316, 503, and 506 in the Inventory of Agricultural Research.

The measure of price variations in equation (4) is the coefficient of variation calculated by estimating the weighted variance of prices in each state:

$$\text{coefficient of variation} = \frac{\sqrt{\Sigma\, q_i^2\ \sigma p^2{}_i + 2\Sigma q_i q_j \operatorname{cov}(P_i P_j)}}{\Sigma E(P_i q_i)}$$

where $\sigma p^2{}_i$ is the variance of P_i, $\operatorname{cov}(P_i P_j)$ is the covariance of $P_i P_j$ and $E(P_i q_i)$ is the expected value of gross returns. The variable is included to account for the fact that allocative error should be greater in states with more variable prices from year to year.

Results of Product Supply and Input Demand Estimation

Results from fitting the output supply and input demand equations to the 92 pooled observations are presented in Tables 2 and 3. The six New England states plus Alaska and Hawaii were omitted in data estimation because of the absence of substantial numbers of products, particularly grains. An indication of goodness of fit is provided by the R^2 obtained from single equations OLS estimates of the individual equations. These measures are .68 for small grains, .65 for other grains and potatoes, .65 for other crops, .90 for hay, .40 for poultry, .90 for other livestock, .48 for feed, .82 for fertilizer, .94 for fuel, and .89 for labor. All own-price coefficients on outputs and inputs have the expected signs except for other crops and poultry and those coefficients were non-significant at the 5% level. Other grains and other livestock also were non-significant at the 5% level. A number of the estimated coefficients on cross prices and fixed factors exhibit low levels of significance. Among the fixed factors, capital strongly and positively affects the demand for feed, fertilizer, fuel, labor and the supply of small grains, other grains, hay, other crops, and livestock. The expected sign on the research variable is negative because it represents the "α" coefficient from a quadratic distributed lag. Research increases the demand for fertilizer and the supply of "other crops". Breeding stock reduces the demand for fertilizer but increases the demand for fuel and labor. Not surprisingly it increases the supply of livestock and is also positively correlated with the supply of hay.

Among the price variables, fertilizer and feed and fuel and feed are complements but other input-input cross-price effects were non-significant at the 5% level. Higher feed prices reduce the supply of hay, but contrary to expectations, increase the supply of livestock. A higher price of fertilizer reduces the "other" grains but contrary to expectations, increases the supply of small grains. A higher labor price reduces the supply of small grains. "Other crops" and livestock are complements. The dummy variables on other grain and poultry had little effect. A good deal of information could be obtained from these equations by calculating elasticities, factor biases, rates of return on research, etc. The major purpose of estimating this set of equations, however, is to provide parameters which will enable the calculation of π^t and the estimation of equation (4). The results of that analysis are presented in the next section.

Table 2. Estimates of Output Supply Functions for U.S. Agriculture, 42 states, 1978-1982.[a]

	Output Supply Equations					
Explanatory Variables	Small Grains	Other Grains	Hay	Other Crop	Poultry	Live-Stock
Normalized Prices						
Feed	.011	-.009	-.01	-.005	-.009	.003
	(1.89)	(1.01)	(2.58)	(1.36)	(1.70)	(2.05)
Fertilizer	.02	-.013	.001	-.0008	.002	.0005
	(4.24)	(4.78)	(.19)	(1.22)	(.20)	(.11)
Fuel	-.0006	-.0002	.0007	.00002	.135	-.177
	(1.17)	(.77)	(1.45)	(.29)	(.98)	(1.71)
Labor	-.02	-.009	.01	.0004	.155	.02
	(1.58)	(2.03)	(1.01)	(.38)	(1.96)	(.51)
Small Grains	.125	-.02	-.03	-.006	-.007	-.007
	(3.86)	(.88)	(1.20)	(1.02)	(.38)	(.72)
Other Grains	-.02	.03	-.02	-.002	.015	.002
	(.88)	(.70)	(1.51)	(.23)	(1.28)	(.42)
Hay	-.03	-.02	.08	.001	.003	-.03
	(1.20)	(1.51)	(2.28)	(.27)	(.12)	(2.82)
Other Crops	-.006	-.002	.0010	-.003	.0009	.001
	(1.02)	(.24)	(.27)	(.47)	(.21)	(.84)
Poultry	-.007	.02	-.003	.0009	1.79	-1.14
	(.38)	(1.28)	(.12)	(.21)	(-.30)	(.45)
Livestock	-.007	.002	-.03	.001	-1.14	2.55
	(.71)	(.42)	(2.82)	(.84)	(.44)	(1.11)
Other G.X.D_1	.009	.004	.001	-.007	-.002	-.0008
	(1.55)	(.45)	(.27)	(.86)	(.34)	(.54)
Other C.X.D_2	.02	-.03	-.01	-.007	-.0004	-.004
	(1.21)	(1.12)	(1.34)	(.32)	(.03)	(.85)
Fixed Factors						
Land	.001	-.03	-.02	.0005	-.004	.005
	(.18)	(2.98)	(3.77)	(.06)	(.74)	(3.17)
Rain	-2.48	13.42	-.78	7.61	2.74	.71
	(.71)	(2.23)	(.33)	(1.65)	(.98)	(.85)
Education	.003	.0004	-.007	-.01	-.02	.0005
	(.20)	(.02)	(.83)	(.70)	(1.47)	(.15)
Extension	.000001	6.45^{9}	-9.7	-.000003	4.15^{-7}	-2.17^{7}
	(1.37)	(.004)	(1.51)	(2.63)	(.54)	(.92)
Research[b]	4.81^{9}	1.97^{9}	-1.29^{-9}	-1.9^{-8}	3.43^{9}	-1.36^{-9}
	(1.44)	(.35)	(.56)	(4.57)	(1.26)	(1.53)
Capital	15.27	27.46	6.35	4.90	4.00	1.52
	(4.82)	(5.26)	(2.99)	(1.31)	(1.50)	(1.75)
Breeding Stock	-.37	-.29	3.16	.18	.005	.33
	(1.01)	(.61)	(13.07)	(.36)	(.01)	(3.55)
Other						
D_1	81.6	-3.16	-37.8	-31.35	6.77	3.82
	(3.32)	(.07)	(2.38)	(1.0)	(.35)	(.63)
D_2	-60.4	-61.23	3.85	113.7	-3.02	-3.00
	(1.99)	(1.17)	(.19)	(2.82)	(.12)	(.38)
Intercept	-170	29.62	-49.2	85.8	109.9	1.03
	(1.72)	(.17)	(.72)	(.70)	(1.41)	(.04)

[a] t-statistics in parenthesis.
[b] α coefficient on quadratic distributed lag.

Table 3. Estimates of Input Demand functions for U.S. Agriculture, 42 states, 1978-1982.[a]

Explanatory Variables	Input Demand Equations: Feed	Fertilizer	Fuel	Labor
Normalized Prices				
Feed	-.012	-.003	-.0002	.0003
	(2.87)	(3.03)	(3.49)	(.69)
Fertilizer	-.0026	-.005	-.00006	.007
	(3.03)	(2.26)	(.35)	(1.50)
Fuel	-0002	-00006	-.36	-.002
	(3.49)	(.35)	(8.60)	(.77)
Labor	-.0009	.007	-.002	-.06
	(.67)	(1.50)	(.79)	(1.32)
Small Grains	-.011	0.02	.0006	-.02
	(1.89)	(4.24)	(1.17)	(1.58)
Other Grains	.009	.013	-.0002	-.009
	(1.01)	(4.78)	(.77)	(2.03)
Hay	.011	.001	.0007	-.01
	(2.58)	(.18)	(1.45)	(1.02)
Other Crops	.005	.0009	-.00002	-.0004
	(1.36)	(1.22)	(.29)	(.38)
Poultry	.009	.0015	-.136	-.155
	(1.70)	(.20)	(.97)	(1.96)
Livestock	-.003	-.0005	.177	-.02
	(2.06)	(.11)	(1.70)	(.51)
Other G.X.D_1	-.006	-.001	.00007	.002
	(1.65)	(1.50)	(1.31)	(1.41)
Other C.X.D_2	-.011	-.006	.0005	.01
	(.98)	(2.33)	(2.77)	(2.93)
Fixed Factors				
Land	-.003	.001	.000008	-.007
	(.62)	(1.29)	(.13)	(5.65)
Rain	-3.78	.41	.001	.71
	(1.61)	(.91)	(.04)	(1.05)
Education	-.005	.003	.00001	-.009
	(.58)	(.159)	(.10)	(3.14)
Extension	$-.045^{-7}$	-1.65^{7}	-1.96^{-8}	-2.66^{-8}
	(.72)	(1.31)	(2.04)	(.13)
Research[b]	1.00^{-9}	-1.89^{-9}	-2.99^{-11}	-1.38^{-10}
	(.46)	(4.19)	(.81)	(.18)
Capital	6.58	3.57	.54	7.36
	(3.11)	(8.01)	(15.24)	(10.15)
Breeding Stock	-.33	-.23	.01	.28
	(1.31)	(4.57)	(2.79)	(3.60)
Other				
D_1	-10.2	-1.21	.82	12.79
	(.64)	(.38)	(3.43)	(2.58)
D_2	29.68	6.74	-.71	-22.61
	(1.47)	(1.62)	(2.23)	(3.47)
Intercept	61.4	-4.68	2.26	.99
	(.97)	(.34)	(2.17)	(9.38)

[a] t-statistics in parenthesis.
[b] α coefficient on quadratic distributed lag.

Result of estimating the impact of agricultural research and extension

The difference between actual profits and profits under perfect information was calculated by substituting actual output prices for each state into the profit equation derived with the coefficients from the estimated supply and input demand equations. The results were are follows:

$$(8)\quad \pi^t - \pi^r = \underset{(.13)}{7877} - \underset{(-2.87)}{694.9Ex} - \underset{(-.67)}{.018AER} + \underset{(1.6)}{14.36ED} - \underset{(-.87)}{1235313CV}$$

One would expect the coefficients on EX, AER, and ED to be negative because they are hypothesized to reduce allocative error. The coefficient on CV should be positive because allocative error should be directly related to price variability. Unfortunately ED and CV had unexpected but non-significant signs.[5] The only variable explaining reductions in allocative error is the marketing and management extension variable. The R^2 for the equation is .13. It appears that extension in the management and marketing area has had a greater effect than research in influencing allocative efficiency.

A Note of Caution

Preliminary results above indicate a possible procedure for measuring impacts of agricultural economics research. However, the results of the output supply and input demand estimation were mixed and the dependent variable in equation (8) is only as good as the profit function model used to generate it. That model was estimated previously with only one cross-section and with outputs aggregate into two output indexes (Norton and Norris). The current effort is an improvement over that earlier work because the additional cross section adds needed variability and because aggregation bias is reduced. Aggregation bias occurs because price per pound of commodity often bears an inverse relationship to pounds per acre and per farm when one adds several commodities.

Nonetheless, disaggregation increases corner solution problems (bias due to zero values for some commodities). This problem requires the use of dummy variables or some other procedure. Additional testing also is needed to ascertain the most appropriate groupings of commodities. Another problem that may be creating difficulties in the estimation is simultaneity. It is often said that one of the advantages of the profit function (as compared to the primal) approach is that is that prices are exogenous and therefore simultaneity is not a problem. The use of aggregate data may mean, however, that price is not exogenous.

Additional study is needed on the proper specification (length and shape of lag) of the research and extension variables. Work is currently underway on this topic. Furthermore, policy variables as suggested by Huffman and Evenson are also needed. The profit function model above assumes risk neutrality. If most decision makers are risk averse and attach a cost to uncertainty, the model underestimates the value of AER. Refinement along the lines suggested by Antonovitz and Roe (1986) should be considered.

Equation (8) needs refinements to account for spillovers from agricultural economics research. Finally welfare impacts at the market level should be considered to allow for the distribution of benefits between producers and consumers. In summary, there are many potential pitfalls and improvements needed in the procedure described above for valuing marketing and management research.

THOUGHTS ON EMPIRICAL PROCEDURES FOR ESTIMATING THE BENEFITS OF INSTITUTIONAL AND DISCIPLINARY INFORMATION

A close look at Table 1 illustrates Ruttan's point that much of agricultural economics research is policy or institutionally related. How might one quantitatively measure the impacts of research designed to improve institutions? The net social benefits approach is likely to be the most useful because it allows for calculations of both efficiency and distributional (equity) impacts. Some types of institutional changes (e.g. pricing policies, credit policies) can affect the adoption of technologies. A multi-stage procedure in which the effects of research on affecting the design of particular policies are first assessed, followed by statistical assessment of the impacts of those policies on the timing and magnitude of technology adoption, followed by an evaluation of the economic impacts of those technologies using a net social surplus approach is one possibility. This example illustrates, however, a major difficulty in evaluating SSR or AER aimed at institutional change: it is difficult to conduct an evaluation for a large set of research activities. One of the useful aspects of previous research evaluation work has been the ability of economists to estimate rates of return for large aggregates of research activities. Unless assessments are made for large aggregates like "management and marketing," or "institutional research," or "AER disciplinary" research, the credibility of any rates of return generated is reduced because policy makers can suggest that only successful cases were selected for evaluation. Most observers are perceptive enough to realize that high rates of return to research are generated by the average of some very very successful efforts and some very dry holes. Nonetheless, with a small amount of ingenuity economists should be able to make some calculations for institutional research with some, albeit small, level of aggregation. Given the severity of many rural development problems today and the declining level of support mentioned earlier, the rural development area might be a good place to start.

CONCLUSIONS

Attempts to measure the value of agricultural economics research by agricultural economists may appear to be somewhat self-serving. There is increasing evidence, however, that social science research in general and agricultural economics research in particular may be bearing a disproportionate share of recent tightening of research budgets especially at the federal level. Economic theory provides some guidance for conceptualizing AER impacts. Measurement procedures are available, especially for research which provides management or price information. Evaluation of research which provides institutional or disciplinary information will likely be more difficult but some attempt should be made, at least for the former. One has to be more pessimistic about the potential for evaluating disciplinary or basic SSR. We have little success with such evaluations even for research which eventually led to new technologies.

FOOTNOTES

1 Bullock; Bullock, Ray, and Thabet; Thabet, Ray and Bullock; and Freebairn (1976, a,b) consider the implications of decomposing the supply response function into a planned supply curve and a current period supply curve. The planned supply curve is a function of producers' forecast price with the forecast price determining the position of the current period supply curve. The latter is more inelastic due to the difficulty of making short run production adjustments.

2 Muth's approach to defining a rational expectation was in terms of conditions on just the mean value of a distribution. An alternative definition of a rational expectation of a variable is that the actual value and the anticipated value of the variable have the same probability distribution.

3 The decision theory approach can be summarized as follows: A variety of actions are open to the decision maker, $a_1, a_2 \ldots a_m$. Several states of nature $S_1, S_2 \ldots S_n$ are also possible and the decision maker has some knowledge of the likelihood (prior probability) of such state occurring, $P(S_i)$. With a given amount of knowledge, the decision maker will choose the action a_i which maximized his expected utility. The expected utility of the jth action is $\Sigma_i u(aj|S_i)P(S_i)$. Now if additional information, $Z_1, Z_2 \ldots Z_m$ becomes available to the decision maker and he has knowledge of the probability of the information coming true, i.e., $(Z_j|S_i)$. By Bayes Theorem:

$$P(S_i|Z_j) = \frac{P(S_i)P(Z_j|S_i)}{\sum_i P(S_i)P(Z_j|S_i)}$$

The revised expected value of aj is now $\sum_j u(ajSj)P(S_i Z_j)$. The value of additional information is the difference between the maximum utility with the without the information and this can be compared with the cost of obtaining the information.

4 Small grains = wheat, barley, oats, rice

Other major grains and potatoes = corn, sorghum, soybeans, peanuts, potatoes
Other crops = sunflowers, sugar beets, sugar cane, cotton, tobacco, peaches, apples, grapes, oranges, grapefruit, vegetables.
Poultry = broilers, chickens, turkey, eggs.
Other Livestock = cattle, hogs, sheep

5 The number in parenthesis for equation (8) are t tests.

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