DEVELOPMENTS IN THE ECONOMIC THEORY OF INFORMATION

Ludwig M. Eisgruber*

I. Introductory Comments

Neither theory nor methodology exist to address the economics of information adequately, and until recently little effort was made to overcome this deficiency. A number of factors contribute to this deficiency: (a) For most information systems, particularly the public information systems, there is no market price that would suggest the value of information and information systems; (b) Information is not a physical good and, therefore, lacks the concreteness that provides a basis for valuing many items such as, for example, a reclamation project; (c) Most information systems do not have an impact that is observable in easily measurable variables. Therefore, currently existing econometric techniques are of little assistance in estimating information values; (d) Public and private value of information may differ significantly.

Interest in this topic has grown substantially in the past decade, particularly as far as agriculture is concerned. Task forces within USDA, the American Agricultural Economics Association, hearings at OMBA, FAO meetings, Bureau of Census deliberations, NASA commissioned studies--all attest to heightened interest in the area of economics of information. Several developments contribute to this upsurge in interest: (a) Costs of information and information systems have risen rapidly; (b) Income distributional impacts of differently structured information systems are recognized; (c) There is increasing understanding that our ability to

*Ludwig M. Eisgruber is professor and head, Department of Agricultural and Resource Economics, Oregon State University.

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conceptualize is limited by data; (d) Related to the above is the growing awareness that during the past decade our profession may have relied too heavily on deductive analysis without proper concern for the relevance of the data base. The result is that an increasing amount of work was completed with increasingly irrelevant data.

The aforementioned developments quickly lead to recognition that economists had, to date, not developed a solid base of concepts and theories useful for the analysis of economics of information.

II. Some Basic Concepts

1. Data vs. Information

Data are not information. The demand for data is generated by the need to make decisions on problems, but decision makers rarely use raw data. Rather, there are intervening acts of interpretation, through statistical and economic analysis, policy staff and political evaluation, etc., which transform data into information by placing them in a specific problem context to give meaning to a particular decision. Consequently, an information system includes at least the following: (a) Data system (collection, storing, processing, retrieval); and (b) Analytical capabilities to interpret the data (theory, methods). This implies that unless economic theory and economic statistics meet on common conceptual ground, there can be no mesh between empirical analysis and theory, that is, between the inductive and the deductive process of "knowing" (Bonnen).

Several significant conclusions follow. For one, development of an economic data base cannot be left to "others." It is here that agricultural economists in the past decade may have failed in a fundamental way. This happened when the philosophy developed that, at the very minimum, data collection should be left to others and may be more likely that those economists who were involved in data collection and data system design are economists of inferior quality. Second, since institutions have changed and circumstances have changed, should not theories and data bases also have changed? Third, to what extent have the aforementioned emerging needs and general concepts been captured in the development of a theory or theories of information? The following comments are designed to provide an overview of developments and current status.

2. Related Areas

Those who have followed research in at least two other areas will recognize similarities between general approaches used in those areas and the general approaches discussed below on the economics of information. These two other areas are those of (a) benefits of research and (b) technology assessment. This should not be surprising, as the research process produces information.

3. Agreement, Controversy

It has already been alluded to but should now be stated explicitly, that no integrated operational theory or methodology exists for placing value on information or for selecting the most appropriate information system. In this respect, it should be pointed out that the government policymaking process and the increased emphasis on rigorous program evaluation contributes to what has been called the "mythology of methodology." While present policy and philosophy may call for a rigorous evaluation of all programs, it must be recognized that this requirement calls for something which exceeds our current ability to conceptualize, and certainly to empirically analyze. Many questions concerning the value of information fall into this category.

III. A General Model

Economics of information deals with the question of selecting that information system from among many which will provide the largest benefit over time. A general model of the economics of information can be gleaned from a number of writings (Eisgruber, Marschak, Menges, Miller), and formulation of such a model of economics of information can appear to be deceptively simple. To demonstrate its underlying complexity, let us examine a general model along lines suggested by Marschak:

(1) Max: $D = E(g) - E(k)$

where $E(g)$ = expected gross payoff

and $E(k)$ = expected cost

and, further,

(2) $E(g) = G(\lambda, \alpha; \Pi, \gamma)$

(3) $E(k) = K(\lambda, \alpha; \Pi, \chi_\lambda, \chi_\alpha)$

Where λ = The process of inquiring (collecting information, experimenting);

α = the process of deciding;

Π = probability that certain events will occur once a decision is made;

γ = benefit (payoff) function;

χ_λ = cost of inquiring;

χ_α = cost of deciding.

The semicolons in Equations (2) and (3) separate the entities "controlled" by the manager from those "noncontrolled" by him.

This model is still relatively simple, at least on the surface. But let us examine the components further. For instance, which decision criterion should be applied in the maximization process: Bayes' criterion, Wald's mini-max criterion, etc.? Should the objective be to maximize net social benefits regardless of distribution, or should income distribution (producers versus consumers; rich versus poor; producers versus processors; developed versus less-developed countries; etc.) be the overriding criterion, or which combination of the two? Another consideration is stability of economic and other processes as well as a host of qualitative aspects. Concerning λ, the process of inquiring, what amount of time and money should be spent on gathering information about the outcome function? How should one proceed if no preference ordering at all is given among the outcomes? How exact and how detailed should the information about the cost function be? How, if necessary, should this information be obtained? Is a sample to be drawn? Which variables are characteristic of the states of nature? Etc. In Equations (2) and (3), Π, the probability that certain events will occur once a decision is made, depends both on the probability function associated with the outcome of a particular action given a certain state of nature as well as the probability functions associated with various states of nature. Thus, knowledge of these probability spaces is assumed. In reality, such knowledge is rarely available.

Thus, while the above all-encompassing general model is attractive to the reflective thinking mind, reality dictates a considerably less all-encompassing approach. Following this line of reasoning is likely to lead to the conclusion that, due to differing circumstances, different operational systems are appropriate and that the pursuit of the one ultimate operational system is not as productive as the concentration on individual improvements. However, the comprehensive concept will aid in deciding which of the many possible individual theories and information systems resulting therefrom should receive the highest degree of attention.

IV. Manageable Approaches: Some Schools of Thought

A review of work to date suggests three different approaches (schools of thought). These will be discussed in turn and are as follows: (a) decision theoretic approach; (b) net social benefit approach; and (c) scoring approach.

3. Decision Theoretic Approach

This approach readily reveals many of the components identified for the general model. The theoretical basis for this approach was developed by such pioneers as Marschak and utilized in empirical agricultural economic analysis by Baquet, Boehlje, among others. The approach rests on the assumption that several future states of nature are possible. It is not known for certain which of these states of nature will exist, but the likelihood (probability) of each situation is known. A variety of courses of action are presumed to be available to the decision maker and, depending on the course of action taken and the particular situation actually occurring, the results (payoff) will differ. Stated more concisely, the decision theoretic approach is basically as follows:

Action: A_i; $i = 1, \dots, m$

States of Nature: S_j; $j = 1, \ldots , n$

Payoff: x_{ij}

Probability of S_j: p_j

Expected Utility: $V(\cdot)$

Then, with a given state of knowledge:

(4) $V(A_i) = \sum_j p_j \cdot V(x_{ij})$ for $i - 1, \ldots , m$

Suppose information becomes available. This will modify the p_j's according to the Bayes' Rule. Let the modified probabilities be identified by $p_{j/I}$. But there is a cost associated with obtaining this information. Let us designate this cost as C(I). Now

(5) $V(A_{i/I}) = \sum_j p_{j/I} V \cdot (x_{ij}) - C(I)$.

It is now possible to evaluate the value of alternative information systems. The decision theoretic approach provides a way for a systematic examination of these various strategies. It also permits the recomputation (or modification) of the likelihood of certain situations coming true as a result of an improved information system. The major problem with the approach is that estimation of the likelihood (probabilities) of the various events is a difficult and gigantic task. As a result, this approach has so far been primarily used for relatively simple micro or firm problems (e.g. value of frost forecasting information in preventing frost damage in orchards). However, a few examples of this approach to the solution of aggregate problems are becoming available (e.g. Bradford).

4. The Net Social Benefit Approach

Although the idea of measuring social benefits was proposed as early as 1844 by Dupuit, it was not until 1972 that this approach was used in an empirical analysis of an information system (Hayami and Peterson). In very simple terms, the argument is that lack of information (or wrong information) is equivalent to a shift in the perceived supply (or demand) functions and thus impact on net social benefits (NSB). Specifically, let NSB be defined as

$$(6)\quad NSB = SB - SC$$

$$(7)\quad = \int_{q_o}^{q_1} f(q)dq - \int_{q_o}^{q_1} g(q)dq$$

where SB = Social benefits

SC = Social costs

$\int_{q_o}^{q_1} f(q)dq$ = area under demand function (between q_o and q_1)

$\int_{q_o}^{q_1} g(q)dq$ = area under supply function (between q_o and q_1)

With perfect information, NSB will be maximized. Imperfect information on, say, available supplies will affect pricing and inventory operations, which will later have to be corrected as additional information about the true supplies becomes available. The result is reduced NSB. The value of an improved information system is $NSB_1 - NSB_2$, where NSB_1 and NSB_2 are, respectively, the values of NSB (in 6 and 7) evaluated in terms of the improved and the old information systems.

A variety of techniques exists to estimate the relevant relationships; they may be econometric or simulation techniques. Supply functions, for instance, may be estimated directly or built up from production functions. Changes in consumer/producer surplus can be separated. Under certain conditions, certain assumptions might be made about elasticities, avoiding the need to estimate them. Elasticities from other studies might be used.

In its simplest form, this approach makes the usual assumptions of perfect competition, perfect mobility, statics. However, considerable progress has been made in methodology (Bradford, Heiss). Models (and associated empirical analyses) are available which permit the assessment of the value of information over several years and with monthly time intervals within years. Dynamic programming was used to solve the model. The same researchers also consider more than one market (i.e. domestic and international), and estimate the value of improved forecast information with Bayesian speculators.

5. Scoring Approach

Few people would classify the "scoring approach" as deserving of the title of an "economic theory of information." The approach nevertheless deserves mention if for no other reason than to point out that the complexity of the economics of information systems often defies analysis by available economic theory and methods. The scoring approach may then be used.

Scoring models are relatively simple procedures to formalize the choice of an information system. Key evaluators (users, scientists, policymakers) are called upon to express their evaluation of various information systems (or the systems' components). Several evaluation criteria can be considered, but they will have to be weighted as to their importance. Schemes for scoring are generally simple, but can be very structured. They may also be demanding with respect to data requirements.

The simplicity of the scheme can mislead the evaluators into thinking that the problem is simple. Also, contrary to first impression, this approach is not inexpensive, as it requires much time input from very expensive and scarce talent.

The "Panel on Methodology for Statistical Priorities," of the National Research Council, has recently recommended this approach for the evaluation of various statistical systems. The National Academy of Sciences Study Team on Information Systems for World Food and Nutrition has also used this approach in the development of its recommendations to the Academy's "World Food and Nutrition Study."

V. Concluding Comments

Those concerned with economics of information and with the design of information systems are faced with a dilemma of several dimensions. For one, while the design of a monistic system appears attractive, it becomes quickly evident that it is beyond practical capabilities. This leads to a number of separate, specialized systems. To the extent that these systems influence or represent social systems, such separate and specialized systems tend to fragment the social decision process with the danger, if not certainty, of externalities.

Economists concerned with the economics of information will need to be concerned with institutional changes. This concern is necessary because problems addressed by society change over time, thus requiring changes in information systems. However, institutions tend to institutionalize information systems, and therefore, make them progressively less effective.

The distributional impact of information of all types needs analysis. Such distributional impacts have two directions. For one, there is the question of the responsibility of the public to provide information so as to counteract the income distributional impact of private information systems. The provision of crop estimates, which are accessible and equally available to all, is one of these examples. The second direction deals with the income distributional impact of public information. Purported bias towards large farms of public information emanating from the Agricultural Experiment Station is an example of this dimension.

Finally, all countries and the public as well as the private sectors spend considerable amounts of resources on the development and maintenance of information systems. Yet, as economists, we have, to date, provided little by way of assessing the effectiveness of these information systems.

REFERENCES

1. Baquet, A.E., A.N. Halter, and F.S. Conklin, "The Value of Frost Forecasting: A Bayesian Appraisal," AJAE, 58:511-520, August 1976.

2. Boehlje, M. and L.M. Eisgruber, "Strategies for the Creation and Transfer of the Farm Estate," AJAE, 54:461-472, August 1972.

3. Bonnen, J.T., "Assessment of the Current Agricultural Data Base: An Information System Approach," A Survey of Agricultural Economics Literature, Vol. II, University of Minnesota Press, 1977, pp. 386-407.

4. Bradford, D.F. and H.H. Kelejian, "The Value of Information for Crop Forecasting with Bayesian Speculators: Theory and Empirical Results," ECON, Inc. (no date).

5. Eisgruber, L.M., "Managerial Information and Data Systems," AJAE, 55:921-936, December 1973.

6. Hayami, Y. and W. Peterson, "Social Returns to Public Information Services: Statistical Reporting of U.S. Farm Commodities," American Economic Review, 62:119-130, 1972.

7. Heiss, K.P., "Economic Benefits of Improved Information on World-wide Crop Production," ECON, Inc., Report No. 76-243-1, March 1977.

8. Marschak, J., "Efficient Choice of Information Services," Working Paper No. 136, Western Management Science Institute, University of California, Los Angeles, May 1968.

9. Menges, G., "Vorentscheidungen," Operations Research Verfahren, Vol. 2, Anton Hain, 1965.

10. Miller, T.A., "Observations on the 1978 Economic Evaluation of LACIE," ERS, USDA, August 1977.