What Value is Agricultural Economics Research?

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Economists have made significant contributions to our understanding of the impacts of technology-oriented agricultural research. They have made fewer contributions to our understanding of the benefits of social science research (SSR), including agricultural economics research (AER). The need to evaluate AER arises both from accountability concerns and from the need to make resource allocation decisions across agricultural research programs.

Studies by Gardner, Lindner, Smith, Norton and Schuh, Norton and Alwang, and Zilberman and Heiman have identified many of the key issues in AER evaluation, and there is general agreement that the primary output of AER is information. However there remain relatively few quantitative evaluations of AER, with the exception of a few simple examples in the aforementioned studies. Lindner, Gardner and others have suggested a Bayesian decision theory approach may be appropriate for valuing research information. This paper briefly reviews several of the key issues in AER evaluation and takes a critical look at the strengths and weaknesses of using decision theory (DT) for that purpose. It presents three examples that illustrate how DT and economic surplus analysis can be combined to evaluate the benefits of economics or agricultural economics research. The examples include research directed at (1) assessing the economic benefits of a food safety program, (2) developing or refining risk management programs for U.S. farmers; and (3) reducing the bias in calculating the U.S. consumer price index (CPI). The purpose of the examples is not to generate an average rate of return to AER, but to illustrate the feasibility of using subjective probabilities in a DT approach to AER evaluation, and to provide general conclusions about factors influencing the size of the research benefits estimated with DT.

Issues in Evaluating AER

Several issues complicate the quantitative evaluation of social science research, including AER. First, research in agricultural economics is diverse, and its outputs can be difficult to measure as they are imbedded in recommendations, institutions, or quantitative methods. Frequently these outputs are not valued in the market, and they may be aimed at a variety of objectives related to efficiency, risk, or distribution. Diverse outputs and multiple objectives make it difficult to evaluate AER in the aggregate, forcing the evaluator to identify the nature of research conducted and the objectives targeted. In a few broad research areas such as marketing and management research, where the immediate clients are producers, it may be possible to econometrically establish a relationship between AER research and changes in economic efficiency, and hence conduct a relatively broad statistical evaluation (Schimmelpfennig, O’Donnell, and Norton). However, most AER attempts to improve institutions and
the immediate users are not producers or consumers but decision-makers that design programs and policies (Ruttan, 1984). For research of this type, econometric assessment is less likely to be fruitful, and a case study approach may be required.

A second set of issues relates to causality and apportioning credit. Regardless of the evaluation approach, establishing causality between AER and specific decisions or institutional changes is a challenge. AER is usually only a single input in a decision-making process that involves political and other factors. Apportioning credit can also be difficult because several pieces of research, including basic research, may contribute to a single policy or institutional change, or to a decision by an economic agent.

Third, timing of AER is important as advice offered after a decision is made is worth little and timeliness influences the likelihood that recommended changes will be adopted. Timeliness depends in part on changes that occur in an economy, in nature, or in technology. The value of social science research is very much related to the need to adjust to change or disequilibria (Schultz).

Finally, AER research evaluations face a credibility problem because economists are evaluating themselves. The audience is being asked both to buy into the methods employed and to accept the findings of self-evaluators. This dual burden implies the need to carefully document and justify methods of welfare measurement as well as data gathering procedures.

Conceptual Framework
While the issues above, and others, complicate AER evaluation, they do not necessarily present insurmountable problems. The economic value of AER stems primarily from its effects on economic efficiency (usually allocative efficiency) through reduced uncertainty about the optimal (or a preferable) way to allocate resources, or the optimal (preferable) design of a policy or institution. Even the gains from research aimed at distributional or environmental concerns can be conceptualized in efficiency terms, to the extent that such research assesses efficiency tradeoffs involved in achieving these objectives. Environmental benefits from research generally stem from reduced externalities, which represent non-market efficiency gains. Basic research also can contribute to efficiency by lowering the cost of designing institutional changes or of developing recommendations for producers or consumers. Essentially, AER substitutes knowledge and analytical skill for the more expensive process of learning by trial and error (Ruttan, 1982).

Because AER obtains its value in part through reductions in uncertainty, it can help decision-makers by providing information that improves their ability to predict outcomes of their actions. This information may not be definitive, but hopefully at least is better than what was available before (Hirshleifer). It could of course be worse, with the possibility therefore of having no value or even
negative value. In some cases, AER might actually lead to greater uncertainty and yet have a positive value if strongly held prior but erroneous beliefs are called into question.

Understanding the value of AER requires an understanding of the interactions between changes in market-level efficiency and levels of uncertainty. Efficiency gains at the aggregate or market level depend not only on the amount of uncertainty facing individuals and the extent of its reduction per micro-level decision-maker, but also on the degree of diffusion of AER results and on the value of the affected economic activities. Reducing uncertainty about an economically trivial decision is worth little, even if the uncertainty was large and the reduction great. Much of the literature on the value of information focuses on the ex ante value of information to micro-level decision makers, with little attention to the more aggregate level so critical for AER evaluation. Exceptions to this statement are a set of studies that focus on the value of more accurate market or price information (e.g., Hayami and Peterson, Freebairn, Bradford and Kelejian, 1978).

Another reason why it is important to consider the aggregate impacts of research is that AER can affect the value of the information by influencing the market. For example, research that produces commodity outlook information may cause speculative inventory holders to revise their prior probability distribution, but it also may affect the commodity price distribution itself if large numbers of people act on the information. Hayami and Peterson take this idea and develop an economic surplus measure for the value of commodity outlook information. They view information as a message that alters perceptions of where the true supply or demand curves lie. Erroneous information distorts production and inventory decisions. Therefore one can use economic surplus analysis to measure improvements in social welfare and then compare the gains to the cost of providing more accurate information. This same approach could be used to measure the effects of other types of AER. However, even highly accurate current information may still have considerable forecasting error. Therefore an approach to valuing information that allows the decision-maker to learn and revise probabilities of uncertain events over time is potentially helpful. Bradford and Kelejian (1977, 1978) suggest a Bayesian decision theory approach in combination with economic surplus analysis. They apply this combination approach to assess the value of wheat crop forecasting. Norton and Schuh use it to evaluate soybean outlook research, using historical data to arrive at the necessary probabilities. Lindner and Gardner prescribe its application for evaluating a broader set of research topics in agricultural economics. Gardner provides a simple example, using subjective probabilities to obtain estimates of the price elasticity of demand.

Methods for Valuing Research Information
Bayesian decision theory (BDT) can provide a useful conceptual framework for valuing information that reduces uncertainty (Hirshleifer and Riley, 1995). Ultimately, decisions by producers, consumers, or
policy makers are based on subjective beliefs. BDT indicates how objective knowledge can lead individuals to revise their beliefs. By structuring the problem in terms of a payoff matrix (in which the payoffs can be represented by economic surplus estimates), and prior, joint, conditional, and posterior probability matrices, BDT may facilitate calculation of the value of information generated by economics and agricultural economics research.

The following is a brief summary, based on Hirshleifer and Riley, of the BDT approach to valuing research information. A variety of actions or policy decisions are assumed open to the decision maker, \( x = (1, \ldots, X) \). Several states of the world, \( s = (1, \ldots, S) \), are also possible and the decision maker has some knowledge of the (unconditional) prior probabilities of such states occurring, \( P(S) = \pi_s \), with \( \Sigma_s \pi_s = 1 \). The individual’s decision, or choice of action, interacts with the state to determine an associated consequence \( c_{xs} \). With a given amount of knowledge, the decision maker will choose the action \( x^* \) that maximizes expected utility: Max \( U(x; \pi) = \sum_s \pi_s v(c_{xs}) \), where \( v(c) \) is a preference-scaling function.\(^1\)

Consequences of terminal choices, with no new information that might cause individuals to revise their beliefs, are presented in table 1, columns C and D, rows 5 –7, along with the expected values of the various actions (row 8, columns C and D) given the prior probabilities in column E.

If additional information becomes available to the decision maker and he/she has knowledge of the probability of that information being true, then he/she might follow a process to convert prior probabilities into posterior probabilities and reassess the optimal terminal action. The value of the new information is the difference between the maximum utility with and without the information. With an AER evaluation, this value of research information is subsequently compared with the cost of the research.

Given the likelihood matrix, the joint probability of state \( s \) and message \( m \) can then be calculated by multiplying \( L \) by the prior probabilities, thereby creating a joint probability matrix, \( (J = [j_{sm}]) \), as shown in columns B, I, J, K and rows 4-7. The sum of the joint probabilities across all messages and states is unity \((\Sigma_s, m j_{sm} = 1)\). For each state \( s \), summing across each row horizontally in the J matrix gives the prior probabilities \((\Sigma_m j_{sm} = \pi_s)\), also called the marginal state probabilities that will sum to one. For each message \( m \), summing vertically over the states gives the message probabilities \((\Sigma_s j_{sm} = q_m)\), also called the marginal message probabilities, shown in row 8, columns I, J, and K.

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1 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.
Table 1. Spreadsheet Representation of Decision Theory Matrices, Two Actions and Three States

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
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<tbody>
<tr>
<td>2</td>
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<td></td>
<td>Payoff Table Analysis of SSR Benefits</td>
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<tr>
<td>3</td>
<td></td>
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<tr>
<td>4</td>
<td>State (s)</td>
<td>Actions (x)</td>
<td>Priors</td>
<td>Likelihoods (q_{m\cdot s})</td>
<td>Joint Probs. (j_{sm} = \pi_s q_{m\cdot s})</td>
<td></td>
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<tr>
<td>5</td>
<td>s_1</td>
<td>c_{11}</td>
<td>c_{21}</td>
<td>\pi_1</td>
<td>q_{1\cdot 1}</td>
<td>q_{2\cdot 1}</td>
<td>q_{3\cdot 1}</td>
<td>j_{11}</td>
<td>j_{12}</td>
<td>j_{13}</td>
</tr>
<tr>
<td>6</td>
<td>s_2</td>
<td>c_{12}</td>
<td>c_{22}</td>
<td>\pi_2</td>
<td>q_{1\cdot 2}</td>
<td>q_{2\cdot 2}</td>
<td>q_{3\cdot 2}</td>
<td>j_{21}</td>
<td>j_{22}</td>
<td>j_{23}</td>
</tr>
<tr>
<td>7</td>
<td>s_3</td>
<td>c_{13}</td>
<td>c_{23}</td>
<td>\pi_3</td>
<td>q_{1\cdot 3}</td>
<td>q_{2\cdot 3}</td>
<td>q_{3\cdot 3}</td>
<td>j_{31}</td>
<td>j_{32}</td>
<td>j_{33}</td>
</tr>
<tr>
<td>8</td>
<td>E(a_x)</td>
<td>\sum c_{1\cdot s}</td>
<td>\sum c_{2\cdot s}</td>
<td>Message Prob (q_m)</td>
<td>q_1</td>
<td>q_2</td>
<td>q_3</td>
<td></td>
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<td>9</td>
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<tr>
<td>10</td>
<td>Posterior probabilities (\pi_s m)</td>
<td>= j_{sm} / q_m</td>
<td>s_1</td>
<td>\pi_{1\cdot 1}</td>
<td>\pi_{1\cdot 2}</td>
<td>\pi_{1\cdot 3}</td>
<td></td>
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<tr>
<td>11</td>
<td></td>
<td>s_2</td>
<td>\pi_{2\cdot 1}</td>
<td>\pi_{2\cdot 2}</td>
<td>\pi_{2\cdot 3}</td>
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<tr>
<td>12</td>
<td></td>
<td>s_3</td>
<td>\pi_{3\cdot 1}</td>
<td>\pi_{3\cdot 2}</td>
<td>\pi_{3\cdot 3}</td>
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<tr>
<td>14</td>
<td>Expected Surplus (for x_1)</td>
<td>b_{11}</td>
<td>b_{12}</td>
<td>b_{13}</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>15</td>
<td>Expected Surplus (for x_2)</td>
<td>b_{21}</td>
<td>b_{22}</td>
<td>b_{23}</td>
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<td>16</td>
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</table>

The potential posterior probability matrix is then derived to provide the conditional probability of each state given any message m (\pi_{sm} = j_{sm} / q_m). The column sums of this matrix are all unity. The posterior matrix gives an ex ante picture of all the alternative posterior distributions that might come about, depending on which possible AER messages are received. The process of revising probabilities is assumed to follow Bayes' Theorem, which can be stated in several ways: P(S \mid M) = P(S)P(M \mid S)/P(M) = \pi_{sm} = j_{sm} / q_m = \pi_s q_{m\cdot s} / q_m = \pi_s q_{m\cdot s} / \sum S j_{sm} = \pi_s q_{m\cdot s} / \sum S q_{m\cdot s}. Given this belief revision process, 1) the higher the prior confidence (tighter the \pi_s), the more the posterior distribution will resemble the prior distribution, 2) the greater the amount of new evidence, the more the posterior distribution will resemble the likelihood function rather than the prior probabilities, and 3) the more surprising the evidence, the bigger the impact on the posterior probabilities (Hirshleifer and Riley).
The usefulness of Bayes Theorem for AER evaluation is greatest when the likelihoods are known or can be estimated from historical data. In cases where they cannot easily be estimated, it may be possible to elicit the likelihoods or even posterior probabilities directly from decision-makers as suggested by Gardner. The ease with which these probabilities can be obtained may be a determining factor when deciding whether to use BDT to value AER.

For a research program (message service in Hirshleifer and Riley’s terminology) characterized by a particular likelihood function \( L \) and prior beliefs \( \pi \), the expected value of the research information is:  

\[
\Omega(\mu) = \sum_m \sum_s \pi_{sm} q_m \cdot v(c_{sm^*}) - \sum_s \pi_s \cdot v(c_{so^*})
\]

or the difference between expected utility with and without the information, where \( c_{sm^*} \) denotes the income in state \( s \) associated with the best action after receiving the information and \( c_{so^*} \) denotes the corresponding income for the best uninformed terminal action. To assess the consequences of choices made with research information and the value of that information, a payoff matrix using posterior probabilities can be constructed, as shown in Table 1, columns I, J, K and rows 14 and 15. The payoffs are calculated as:  

\[
b_{11} = c_{11} \pi_{11} + c_{12} \pi_{12} + \ldots + c_{13} \pi_{13}, \quad b_{12} = c_{11} \pi_{21} + c_{12} \pi_{22} + \ldots + c_{13} \pi_{23}, \quad \text{etc.}
\]

The optimal action, \( x^* \), is then selected for each research message and multiplied by its corresponding message probability, \( q_m \). These products are summed to arrive at the expected utility with the information. The expected utility without the information is then subtracted to arrive at the value of the message service (in our case an AER program). The payoffs can be represented by economic surplus values to enable calculation of aggregate social benefits due to the AER program.

One advantage of the BDT framework as an empirical approach is that it explicitly links the value of information to the economic theory of uncertainty. A disadvantage is the need to estimate prior and conditional probabilities. In a few cases, these probabilities can be obtained from historical data such as in Norton and Schuh, who assumed that subjective priors could be based on historical price movements over the past 15 years, and conditional probabilities were determined from past outlook projections and actual states of nature that occurred. Gardner’s approach of obtaining prior and conditional probabilities by subjective elicitation is the alternative, although if one is forced to go this route, eliciting posteriors rather than the likelihoods is another possibility (Hardaker, et.al).

A separate issue is the appropriate value-preference or utility function, unless a linear utility function is assumed. As an approximation in an AER evaluation, the linear assumption is probably not unreasonable. Other issues that have been debated for centuries are whether economic agents update their priors in the manner suggested by Bayes theorem, and the concern that the choice of a prior probability can heavily influence the posterior. Finally, it is clear that direct application of BDT for AER evaluation is most helpful for evaluating individual research projects or programs. Attempts to evaluate broader classes of research output such as management research or research directed at classes of institutional
change may be better suited to econometric techniques and other applications of economic surplus analysis.

**Case Studies**

Decision theory was applied to a set of AER and economics research programs to test its usefulness for quantifying benefits of social science research. The results of three of those studies are summarized below. In each case, a structured format was used to collect and analyze the information. That format included a brief description of the research, objectives of the evaluation, results of the research (messages), clientele for the research, decisions influenced by the research (including identification of states of nature and actions), nature of the research benefits, data needs, and phone interviews using questionnaires to elicit information from decision-makers to calculate the probabilities. Benefits were then calculated using a spreadsheet such as the one in table 1. A brief summary of these items for each case is presented below.

**Case study 1. – Risk management research**

Agricultural producers face yield, price, revenue, and other risks that force them to develop risk management strategies. With the shift toward less government intervention in agriculture in the 1990s, the need has increased for farmers to understand available strategies and for public agencies and the private sector to refine risk management alternatives. Forced in part by budget pressures that became severe in the late 1980s, disaster payments to farmers were reduced and were replaced by an expanded set of other, more actuarially sound, insurance mechanisms. Both the public and private sectors are involved to varying degrees in the provision or regulation of crop yield insurance, crop revenue insurance, futures and options markets, and other risk management tools. The Risk Management Agency (RMA) within the U.S. Department of Agriculture coordinates with the private sector in providing crop insurance, and, in the process, is responsible for developing new programs, setting premium rates, and deciding on other key aspects of these risk management programs. Because there are numerous economic issues involved in making these programmatic decisions, the RMA frequently supports and draws on research conducted at the Economic Research Service (ERS) of USDA or at universities in designing or refining its programs. For example, recent work by economists has included analyses of premium rates for revenue insurance (Heifner; Makki and Somwaru, 1999, 2000), the appropriate allocation of risk between the public and private sectors (Dismukes), the economic feasibility of new crop and livestock insurance programs, and the benefits and costs of cost-of–production insurance (Harwood, Coble, and Dismukes). In addition, ERS provides written documentation directed at the public and at policy makers in Congress and their staff,
and has provided briefings for congressional staff about risk management issues. This information is aimed at helping policy makers design and make decisions on public policies and programs affecting risk management in agriculture.

The objective of this case study is to assess the economic benefits of three specific research activities undertaken by the risk management group at ERS in cooperation with universities. Those three are: (1) Analysis of premium rates for revenue insurance, (2) Analysis of the appropriate allocation of risk between the public and private sectors for the Standard Reinsurance Agreement, and (3) Research on the feasibility of establishing crop insurance programs for selected horticultural crops and for livestock. These activities represent just a piece of the risk management program, and therefore the analysis of them was complemented by a qualitative assessment of the benefits of more general risk management bulletins, outlook publications, and briefings by ERS.

Results of Risk Management Research (messages)

1) **Analysis of premium rates for revenue insurance** – Economists at USDA/ERS examined the potential for adverse selection in crop insurance markets when farmers are offered a portfolio of insurance products and coverage levels (Makki and Sowaru, 1999, 2000). Adverse selection occurs because insurance firms cannot easily distinguish low-risk farmers from high-risk farmers because risk varies due to factors such as location and managerial ability. Results of the research are that adverse selection does exist and that farmers signal their risk level by their choice of insurance instrument and level of coverage. Higher risk farmers choose higher levels of coverage and vice versa. By examining risk and other characteristics of farmers who buy different insurance contracts, it may be possible to structure contracts to reflect farmers’ risk profiles. In order for the RMA to set appropriate premium rates for different risk types, it must develop a measure of risk at the individual farmer level. The RMA should adjust information on the actual production history of individual farms with longer individual yield trends and the probability of extreme unlikely events. *Message:* Existing risk premium rates are not actuarially sound, and RMA should develop a measure of risk at the individual farm level.

2) **Standard Reinsurance Agreement** – The SRA specifies the financial terms of delivery and risk sharing of crop insurance products by private insurance companies. The SRA is negotiated periodically by RMA, USDA and representatives of insurance companies selling and servicing federally subsidized crop insurance products. Risk sharing provisions of the SRA allow the companies and the government to share in potential gains and losses of crop insurance policies. ERS has been working with the Deputy Chief economist, USDA, an economist at Ohio State, and RMA to develop models that simulate returns to companies (and costs to Government) of various specifications of SRAs
(Dismukes). USDA used an early version of one model during the 1997 negotiations of the SRA. The models present expected returns as well as estimates of variations in returns based on several measures of the capital at risk by the insurance companies. 

Message: The existing risk sharing between the public sector and insurance companies needs adjusting and the research quantified how much.

3) Expansion of crop insurance program to include specialty crops – The feasibility of extending coverage of the Multiple-Peril Crop Insurance program to some 41 additional crops was assessed in a series of reports for RMA from 1993 to 1998. Conclusions were reached for each commodity with respect to general feasibility and to the optimal geographic targeting of each potential program. Examples of commodities considered include mushrooms, snap beans and cantaloupe (Harwood, 1994, 1995a, 1995b).  

Message: The demand for crop insurance will be large enough to generate benefits in excess of program costs for certain commodities.

4) A substantial ERS report entitled Managing Risk in Farming: Concepts, Research, and Analysis (Harwood, et al) was prepared and followed up with ERS Outlook articles (USDA, ERS) and by briefings. This work was aimed at informing the general public about risk management options but also to inform those seeking to adjust risk management policies and programs. One message: Existing risk management tools are of limited effectiveness in dealing with multi-year risk.

Clientele -- The primary clients of the risk management research program at ERS are the RMA, the Deputy Chief Economist at USDA, and, to a lesser extent, the Farm Service Agency, farmers, and insurance companies. RMA in particular makes direct use of the analyses and frequently funds the research. In addition, publications and briefings have been directed at policy makers in Congress and their staff.

Decisions influenced by the research (states of nature and actions)

The following is a description of the states of nature and actions associated with each of the above topics of risk management research at ERS:

1) Premium rates for crop and revenue insurance – States of nature: 1. Existing premium rates are actuarially sound or almost actuarially sound 2. Existing premium rates are not actuarially sound by a significant degree. Potential actions: 1. Determine rates using existing procedure 2. Expand information used to set rates (i.e. information on individual farms).

2) Standard reinsurance agreement – States of nature: 1. Existing risk sharing arrangement is only slightly slanted in favor of insurance companies. 2. Existing risk sharing arrangement is significantly
slanted in favor of insurance companies. *Potential actions:* 1. Use existing agreement shares 2. Give government a lower share of risk.

3) Expand crop insurance program – *States of nature:* 1. Expanding the crop insurance program to certain specialty crops would be welfare improving 2. Not expanding the program to specialty crops would result in higher welfare than expanding it. *Potential Actions:* 1. Expand the crop insurance program to include certain specialty crops 2. Do not expand the crop insurance program to include certain specialty crops.

4) Reports and publications aimed at farmers and policy makers – *States of nature:* 1. No change in risk management programs or policies. 2. Changes in risk management programs or policies. *Potential actions:* 1. Modify programs or policies 2. Do not modify programs or policies.

*Nature of the research benefits* -- The benefits of actuarially sound crop insurance are of two basic types: a) gains to producers from reduced risk, and b) lower public and private costs for a given amount of risk coverage. The benefits of appropriate risk sharing between the public and private sectors are primarily lower costs to the government for a given level of insurance. Expansion of insurance to specialty crops obtains value from the gains to producers due to lower risk and lower public costs due to reduced disaster payments.

*Data required for the analysis:* (1) Market data for affected commodities, (2) Reduced costs to farmers, (3) Reduced costs to the public sector, (4) Timing of the research and implementation of the results, (5) Costs of the research, (6) Prior probability for each state and likelihood of message given the states.

*Interview Questions* – A list of people who used the risk management information was assembled. Eight people were called and were asked about savings or potential savings in public costs, whether program changes were made as a result of the information provided. More importantly, they were asked for their prior beliefs on the states of nature before and after the research, and the odds that ERS would have correctly predicted each state of nature. Questionnaires were constructed with six questions for each type of risk management research assessed. The key questions were those that elicited the prior probabilities and the likelihood probabilities. Copies of questionnaires are available from the authors.

*Results of the Analysis*

The BDT matrix presented in table 1 requires two basic types of information: the payoffs to include and the probabilities. The payoff matrix is difficult to construct for the risk management program because the benefits that producers realize due to lower risk depends both on quantifying the reduced risk and on the
worth that producers place on lower risk. These values are difficult to estimate without a detailed risk analysis of farmers’ risk preferences. On the public cost side, subsidies for the agricultural risk management programs exceed $1.4 billion per year, including administrative costs of the programs. Therefore, even a small gain in program efficiency can potentially generate substantial public savings.

Public savings however are primarily transfer payments, not welfare gains per se. Welfare gains do result from the reductions in the marginal excess burden of taxation (MEB) as discussed by Ballard, Shoven and Whalley (1985a). They estimate the MEB of tax revenue in the United States to be at least 15% (1985b). Revenue insurance, for example, which costs over $900 million per year in public funds, has an MEB of at least $135 million.

Calculating the savings in program costs due to the research on premium rates is complex because additional premium subsidies have been provided as a result of low farm prices in the past two years. These subsidies substitute in part for price supports that no longer exist due to changes in farm programs. However, we estimate, based on discussions with RMA, that payoffs in the range of those presented in table 2 exist for the two states and actions, for example $20 million if state 2 occurs and action 2 is taken. The senior actuary at RMA indicated that his prior on State 1 occurring was 70%.

Table 2. Payoff Table Analysis of Research on Premium Rates for Revenue Insurance

<table>
<thead>
<tr>
<th>State[s]</th>
<th>Existing Expans</th>
<th>Priors</th>
<th>Likelihoods [q(m[s])]</th>
<th>Joint Probs. [j(sm)] = π(s) q(m[s])</th>
</tr>
</thead>
<tbody>
<tr>
<td>s1</td>
<td>Existing Proced.</td>
<td>10</td>
<td>5</td>
<td>0.7 m1 0.8 m2</td>
</tr>
<tr>
<td>s2</td>
<td>Expand</td>
<td>0</td>
<td>20</td>
<td>0.3 m1 0.2 m2</td>
</tr>
</tbody>
</table>

Marginal Message Probs

| q(m) | 0.62 | 0.38 |

Posterior (π s|m)

<table>
<thead>
<tr>
<th>State</th>
<th>Expected Surplus (Action 1)</th>
<th>Expected Surplus (Action 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>9.032258</td>
<td>3.684211</td>
</tr>
<tr>
<td>S2</td>
<td>6.451613</td>
<td>14.47368</td>
</tr>
</tbody>
</table>

Annual value of research

Total = 5.6 5.5 1.6
felt that the odds of ERS predicting state 1, when it was the case, was 80%, and of predicting state 2 if it
was the case was also 80%. Calculating the joint and posterior probabilities and applying the latter to the
payoff matrix leads to an estimated net economic benefit of $1.6 million, only taking into account the
savings in program costs.

Benefits estimated for the research on the appropriate cost sharing between the public and private
sectors for the standard reinsurance agreement are presented in table 3. This area of risk management
work involves two economic models that have been applied to the problem but are still under revision.
One individual at RMA gave the probabilities shown in the table while another felt that the preliminary
model used thus far had not been particularly helpful in the negotiations. This example raises the point
that the results of this type of analysis are quite subjective, as they are based on the opinions of the
decision-makers that used the research results.

Table 3. Payoff Table Analysis of Research on the Standard
Reinsurance Agreement

| State[s] | Use | Govt | Priors [π(s)] | Likelihoods [q(m|s)] | Joint Probs. [j(sm)] = π(s) q(m|s) |
|---|---|---|---|---|---|
| s₁ | 1 | 0 | 0.7 | 0.9 | 0.1 | 0.63 | 0.07 |
| s₂ | -0.5 | 2 | 0.3 | 0.05 | 0.95 | 0.015 | 0.285 |
| E(ax) | 0.55 | 0.6 |

Marginal Message Probs [q(m)]

| Posterior (π s|m) | S₁ | 0.976744 | 0.197183 |
|---|---|---|---|
| = j(sm)/q(m) | S₂ | 0.023256 | 0.802817 |

Expected Surplus (Action 1) | 0.965116 | -0.20423 |
Expected Surplus (Action 2) | 0.046512 | 1.605634 |

Annual value of research

| Total | 0.6225 | 0.57 |

The payoffs for the research on the feasibility of extending the benefits of the multi-peril crop
insurance program to several specialty crops led to some savings in the Non-insured Assistance Program
(NAP), but the largest benefits were from increased protection for the growers. RMA relied heavily on the
results of the ERS analysis when deciding whether to extend the program. In some cases there were
benefits because ERS research indicated that extending the program to the commodity would not be a cost
effective use of public funds and the report helped RMA respond to political forces that were pressing for
the program. The estimated payoffs in table 4 are based on the 17 commodities for which a decision was
made to extend the program. However, the estimated value of the research of $1.1 million is an
understatement of the benefits because of the value of resources saved on administrative costs for
programs that would have had few subscribers. To develop a program for a single crop may cost as little
as $100,000 but often the cost of establishing a new program will run over $1 million.

Table 4. Payoff Table Analysis of Research on Extending the crop insurance program to
specialty crops

| State[s] | Do not Extend Program | Priors [π(s)] | Likelihoods [q(m|s)] | Joint Probs. [j(sm)] |
|----------|------------------------|--------------|---------------------|---------------------|
| s₁       | -3.0                   | 0.5          | 0.8, 0.2            | 0.4, 0.1            |
| s₂       | 0                      | -6.0         | 0.5, 0.2            | 0.1, 0.4            |

E(ax) -1.5, 2
Marginal Message Probs [q(m)] 0.5, 0.5
Posterior (π(s|m))
S₁ 0.8, 0.2
= j(sm)/q(m)
S₂ 0.2, 0.8

Expected Surplus (Action 1) -2.4, -0.6
Expected Surplus (Action 2) 6.8, -2.8
Annual value of research 3.4, -0.3
Total = 1.1
In addition to the three activities considered above, discussions with individuals at the Congressional Budget Office (CBO) and elsewhere in USDA revealed that the ERS risk management research program has produced data and publications that are used in policy formulation on a continual basis. One individual at CBO described how data in their reports and specific elasticities have been useful to their analysts in designing program provisions, for example on Loan Rate caps in the ‘95 farm bill.

**Case study 2. – Food safety research**

Concerns over food safety have increased over the past few years, due in part to highly publicized outbreaks of food-borne illness linked to *E.Coli* O157:H7 in hamburger and *Salmonella* in poultry products, among others. These concerns have led to new efforts by the Federal government and private industry to promote the safety of the Nation’s food supply. These efforts have included, among other actions, strengthening of the meat and poultry inspection system. USDA now requires that all meat and poultry plants develop Hazard Analysis and Critical Control Points (HACCP) plans to monitor and control production operations. Plants must identify potential food safety hazards and critical control points in their operations. The plants establish critical limits for each control point and monitors and keeps records of the point. The Pathogen Reduction/HACCP rule requires all federally inspected plants to develop and implement written sanitation standard operating procedures. The Food Safety Inspection Service tests for *Salmonella* and the plants themselves test for and keep records of *E. Coli* on carcasses.

Economic analysis can play a role in identifying the benefits and costs of food safety policies and regulations. When considering whether to implement the HACCP rule, the Food Safety Inspection Service (FSIS) of USDA needed a cost-benefit analysis of the rule, as required under Executive Order 12286 for all regulations that have significant impact on society (over $100 million). FSIS conducted its own assessment and then was assisted in refining the benefits and costs by the Economic Research Service (ERS) of USDA (Diet Safety and Health Economics Branch).

The purpose of this case study is to evaluate the economic benefits of the research analysis provided by ERS on the costs and benefits of HACCP. The cost benefit analysis of HACCP provides an example of economic research that assessed both the efficiency and the distributional effects of a proposed regulation.

*Results of the Food Safety Research (message)* -- Results of the benefit cost analysis of HACCP found the benefits to be greater than the costs for all five scenarios it ran (Crutchfield et al, 1997). The five scenarios are shown in table 5 and vary with the effectiveness of pathogen reduction, the discount rate,
and the method for valuing premature death and disability. The low and high columns reflect the range of estimates of the number of food borne illnesses and deaths each year, and the corresponding range in medical costs and productivity losses averted. Even at relatively low effectiveness (20 percent pathogen reduction in the low benefits scenario), HACCP saves at least $1.9 billion in medical costs and productivity losses, and its benefits exceed the $1.1 billion to $1.3 billion in estimated costs. Higher pathogen reduction rates and increased cost estimates for premature death and disability widen the margin between costs and benefits.

*Research Message:* HACCP benefits exceed costs even under conservative assumptions.

**Table 5. Range of HACCP Benefits Under Five Scenarios**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1995 FSIS analysis</td>
<td>90</td>
<td>7</td>
<td>Human capital</td>
<td>8.4</td>
<td>42.1</td>
</tr>
<tr>
<td>Low benefits estimates</td>
<td>20</td>
<td>7</td>
<td>Human capital</td>
<td>1.9</td>
<td>9.3</td>
</tr>
<tr>
<td>Mid benefits estimates</td>
<td>50</td>
<td>7</td>
<td>Human capital</td>
<td>4.7</td>
<td>23.4</td>
</tr>
<tr>
<td>Mid benefits estimates</td>
<td>50</td>
<td>3</td>
<td>Labor market</td>
<td>26.2</td>
<td>95.4</td>
</tr>
<tr>
<td>High benefits estimates</td>
<td>90</td>
<td>3</td>
<td>Labor market</td>
<td>47.2</td>
<td>171.8</td>
</tr>
</tbody>
</table>

Source: Crutchfield et al, 1999.

*Clientele for the research results* -- The results of the ERS analysis of HACCP were supplied to the FSIS administrators for use in deciding upon the economic feasibility of the program and in countering arguments by industry groups that the costs of the heightened food safety rules were greater than the benefits. Congress and the Office of Management and the Budget (OMB) were also involved in using the information provided by the analysis.

*Specific decision(s) influenced by the research (states of nature and actions)* -- The decision to implement HACCP as proposed was facilitated by the positive economic benefits estimated for the program. In decision theory language, there were two states and two possible actions. State one was that the costs of HACCP exceeded the benefits under conservative assumptions on benefits. State two was that the benefits of HACCP exceeded the costs, even under conservative assumptions. Action one was to implement HACCP as proposed. Action two was to not implement HACCP.
Nature of research benefits -- The HACCP research itself calculated economic benefits of the program to society. While these estimates are ex ante in nature, they do provide a reasonable starting point, notwithstanding the opinion of one person interviewed who felt they understated the costs. Therefore the primary issue in evaluating the economics research is to ascertain the role that the research played in facilitating implementation of the HACCP rule.

Data needed for the analysis: (1) cost and timing of the research, (2) prior probabilities that benefits of the research would exceed the costs, (3) likelihood of research message in situation where benefits of HACCP exceeded costs under conservative assumptions, and likelihood in situation where it did not, and (4) benefit figures out of the ERS report on the benefits of HACCP.

Interview questions: Ten people were called who were involved in making the decision on HACCP implementation or in critiquing HACCP. These people were at FSIS or OMB at the time of the discussion or decision on implementation. They were asked about the probability they attached to the belief that benefits of HACCP exceeded the costs even under conservative assumptions on benefits before viewing the results of the benefit cost analysis (prior probability). They were also asked if the benefits do exceed the costs under conservative assumptions, what the odds are that ERS would correctly predict that result (likelihood probability). They were asked if benefits do not exceed the costs, what the odds are that ERS would correctly predict that result. They were asked if the ERS analysis had any influence on the decision to implement HACCP in its current form.

Results of the Analysis: The results of 10 interviews revealed less than a consensus on the contributions of the economics research to the decision to implement HACCP, even among those close to the decision. Several individuals felt it had been quite helpful and were willing to supply the prior and likelihood probabilities shown in table 6. Another person noted that FSIS had done its own analysis first and that had carried the day even though people at OMB and others had criticized the FSIS analysis as too crude and based on unreasonably high estimates of reductions in food-borne pathogens. One can see from table 6 that in a sense both opinions were correct. If we assume the conservative $1.9 billion net benefit is correct, even if state 2 occurs and a net cost is incurred of $500 million, action 1 (to implement) is preferred in both the prior and posterior situations with the revised probabilities having no influence over the decision.

The HACCP case illustrates the general point that economics research may have no measurable value in a BDT framework if the change in probabilities does not reduce the uncertainty very much in relation to the size of a payoff. In the HACCP case, the payoff for action 1 in state 1 was dominant
enough that action 1 would have been undertaken regardless of whether the benefit cost analysis had changed the probabilities as much as they did or not. If the likelihoods had been .95 for message1/state1 and for message 2/state 2 instead of .9, the change would have been great enough to cause a switch to action 2 in state 2 and therefore would have resulted in a positive value for the research.

Table 6. Payoff Table Analysis of HACCP Case

| State[s] | Implement HACCP | Do not Implement | Priors [π(s)] | Likelihoods [q(m|s)] | Joint Probs. [j(sm) = π(s) q(m|s)] |
|----------|----------------|-----------------|---------------|---------------------|-----------------------------------|
| s1       | 1.9            | 0               | 0.75          | 0.9                 | 0.1                               | 0.675                             | 0.075                             |
| s2       | -0.5           | 0               | 0.25          | 0.1                 | 0.9                               | 0.025                             | 0.225                             |

Marginal Message Probs [q(m)]
- S1: 0.964286
- S2: 0.035714

Posterior (π(s|m))
- S1: 0.964286 0.25
- S2: 0.035714 0.75

Expected Surplus (Action 1) 1.814286 0.1
Expected Surplus (Action 2) 0 0

Annual value of research 1.27 0.03
Total = 0

Case Study 3 – Research to Estimate Bias in the Consumer Price Index (CPI)
Changes in the CPI influence public spending and taxes through cost-of-living allowances (COLAs), and measured economic growth and productivity, real wages and poverty rates, and monetary policy. A number of economists have argued that the CPI as measured by the Bureau of Labor Statistics (BLS), overstates inflation. The problem has arisen in part because of the rapidly changing nature of the economy, and the shear size of the task of gathering monthly data on thousands of goods whose quality may be changing, and that are being sold by an evolving mix of retail outlets. New automobiles and computers do more than old automobiles and computers, and items that didn’t exist a couple of years ago
can quickly become major purchases. Another problem is the use of fixed weights for aggregation that fails to account for consumer substitution among commodities.

*Results of Consumer Price Index Research (message)* -- Starting in 1994, economists began publishing estimates of the size in the bias in the CPI (Moulton, p.160, table 1). Alan Greenspan brought the issue into the balanced budget debate in January 1995. In mid-1995, the Senate Finance Committee appointed an advisory committee, the Boskin Commission (1996), to summarize the work being done by economists at BLS and elsewhere. In December 1996, the Commission concluded that the CPI overstates the change in the cost of living by about 1.1 percent.

*Clientele for the research results* – Between December 1996 and June 1999, BLS made seven changes to the calculation of the CPI and announced three additional changes to be implemented (Kingsbury, 2000). The former Boskin Commission members indicated that between .2 and .37 percent of the bias had been eliminated.

*Specific decision(s) influenced by the research (states of nature and actions)* – Three decisions, or actions, concerning revision of the CPI are affected by the economic research. The first concerns the decision to implement the revisions that were made through June 1999. The second concerns further revisions to eliminate most or all of the remaining bias. Finally, a third action not seriously considered by BLS, is not to change the calculation of the CPI for the purpose of eliminating bias. To evaluate how the choice of one of these three actions interacts with different states of the world, we assume that state one is zero to .3 bias, state two is .3 to .8 bias, and state three is greater than .8 bias in the CPI.

*Nature of research benefits* – As part of the process of evaluating specific types of revisions to the CPI, the Congressional Budget Office (CBO) estimated that a .1 percent downward revision in the CPI would save $10.8 billion in Federal expenditures over four years (Ungar and Bothwell). BLS estimated that the cost of one type of revision, one to update the market basket of weights would be about $3.1 million and that the multifaceted 1998 revision to the CPI would cost $66 million. The benefits of revising the CPI greatly exceed the costs when considered from a budgetary standpoint. The distributional impacts are less clear and possibly less desirable. Several large transfer programs, including social security, are affected by changes in COLAs. Two-thirds of households that receive social security or railroad retirement benefits have family income of less than $25,000. Two-thirds of recipients are over age 65. In 1995, social security paid out $332.6 billion. If the CPI were reduced by 1% the benefits going to each of these groups would be reduced by $2.4 billion annually.
Data needed for the analysis: (1) cost and timing of specific actions regarding revisions to the CPI, (2) prior probabilities that the bias is less than .3, between .3 and .8, and greater than .8, (3) likelihood of the research message when bias is less than .3, between .3 and .8, and greater than .8, and (4) benefit figures estimated by CBO.

Interview questions: Nine economists were interviewed who had close involvement with the work on the bias in the CPI. The institutional representation of these economists is fairly wide, including BLS, the Brookings Institution, the Bureau of Economic Analysis (Commerce Department), CBO, GAO, the Social Security Administration, and the original Boskin Commission. They were asked about the probability they attached to the belief that the CPI was biased less than .3 percent and more than .8 percent, before the research that began in 1994 made estimates of the size of the bias (prior probability). They were also asked, assuming there was a bias in the CPI in the ranges mentioned before, what the odds were that economists would correctly have predicted the bias (likelihood probability).

Results of the Analysis: The economists that were interviewed fell into one of three camps. Economists at BLS and close associates refused to give specific probabilities “to stay out of controversy” and avoid any more direct political confrontation with the Commission and those who appointed the Commission. Another economist indicated that it was common knowledge that members had been selected for the Commission because of their prior beliefs concerning a substantial bias in the CPI. Responses to the questionnaire tended to support that position, with high prior probabilities on the existence of a bias given by Commission economists, even before 1994 research offered specific estimates of the size of the bias. The third camp of economists indicated some updating of their beliefs after 1994. More weight has been placed on these responses. There was a 100% probability of economists in the second camp having published estimates of bias. Since it is safe to assume that these economists understood the process of Bayesian updating and could make the required calculations on the fly, it might have been difficult for them, or they might have felt it was inappropriate, to place value on their own work.

The first payoff table for the consumer price index case (table 7a) illustrates the general point that economics research may have no measurable value in a BDT framework if the payoffs are such that one action is always preferred regardless of the state. The value of the research is negligible because the decision is obvious. There is always a higher payoff to revising the CPI down by .3, and this is the amount that the CPI had been revised as of June 1999.

The second payoff matrix (table 7b) considers whether there is value to economics research in considering further reductions in the CPI. The table shows positive value for economics research if there
### Table 7a. First Payoff Table for Consumer Price Index Case

| State[s] | Don’t Revise | Revise Down .3 | Priors \[\pi(s)\] | Likelihoods \[q(m|s)\] | Joint Probs. \[j(sm) = \pi(s) q(m|s)\] |
|----------|--------------|----------------|-------------------|-------------------|-------------------------------|
| m1       | m2           | m3             | m1                | m2                | m3                           |
| s1       | 0            | 6.4            | 0.65              | 0.73              | 0.23                         | 0.04                          | 0.47                          | 0.15                         | 0.03                          |
| s2       | 0            | 7.2            | 0.28              | 0.08              | 0.65                         | 0.27                          | 0.02                          | 0.18                         | 0.07                          |
| s3       | 0            | 8.0            | 0.07              | 0.013             | 0.413                        | 0.574                         | 0.0009                        | 0.031                        | 0.043                         |

\[E(ax)\] 0 6.8  Marginal Message Probs. \[q(m)\] 0.49 0.36 0.15

Posterior \[\pi(s|m)\] = \[(sm)/q(m)\]

| State[s] | (\pi(s|m)) =j(sm)/q(m) |
|----------|------------------------|
| s1       | 0.96 0.42 0.2          |
| s2       | 0.04 0.5 0.5           |
| s3       | 0.002 0.09 0.29        |

Expected Surplus (Action 1) 0 0 0

Expected Surplus (Action 2) 6.5 7.0 7.3

Annual value of research 3.2 2.5 1.1

Total = 0

### Table 7b. Second Payoff Table for Consumer Price Index Case

| State[s] | Revise Down .3 | Revise Down 1.1 | Priors \[\pi(s)\] | Likelihoods[q(m|s)] | Joint Probs. \[j(sm) = \pi(s) q(m|s)\] |
|----------|----------------|-----------------|-------------------|-------------------|-------------------------------|
| m1       | m2             | m3              | m1                | m2                | m3                           |
| s1       | 6.4            | 5.9             | 0.65              | 0.73              | 0.23                         | 0.04                          | 0.47                          | 0.15                         | 0.03                          |
| s2       | 7.2            | 18              | 0.28              | 0.08              | 0.65                         | 0.27                          | 0.02                          | 0.18                         | 0.07                          |
| s3       | 8.0            | 24              | 0.07              | 0.013             | 0.413                        | 0.574                         | 0.0009                        | 0.031                        | 0.043                         |

\[E(ax)\] 6.8 10.6  Marginal Message Probs. \[q(m)\] 0.49 0.36 0.15

Posterior \[\pi(s|m)\] = \[(sm)/q(m)\]

| State[s] | (\pi(s|m)) =j(sm)/q(m) |
|----------|------------------------|
| s1       | 0.96 0.42 0.2          |
| s2       | 0.04 0.5 0.5           |
| s3       | 0.002 0.09 0.29        |

Expected Surplus (Action 1) 6.5 7.0 7.3

Expected Surplus (Action 2) 6.4 13.5 17.4

Annual value of research 3.2 4.8 2.6

Total = 0.015
were further reductions in the bias of the CPI. The annual benefits are $15 million. This number would change from year-to-year depending on the amount of the bias removed and the cost to implement the change. These benefits, measured as a budget surplus, assume all else is constant in the economy, and could continue each year whether more bias is removed or not. We have not considered what the impacts might be of lowering the CPI when all of the bias has been removed. Distributional issues need to be considered further, but it is possible that the disadvantaged are taxed at a higher rate for this correction than society as a whole.

Conclusions
Several conclusions can be drawn from the analysis. First, if one action/state is not highly dominant, it is easier to obtain significant benefits from the research because it is more likely that the optimal action will be influenced by the AER. A corollary is that if one action is always preferred regardless of the state, then the research is worth nothing because the decision is obvious. Another related point is that the number of states and actions can easily influence the results. When there are fewer actions and states, it is more likely that one action will dominate as the preferred choice, reducing the chances that new information will cause a change in behavior from what would have occurred with prior information only. However, as the number of states and actions grow, the more difficult it is to elicit subjective probabilities because the number of questions required expands rapidly.

Second, the size of the difference between prior and likelihood probabilities influences the size of the benefits, and whether any benefits are realized at all, as illustrated above in the HACCP case. In other words, the more surprising the information, as reflected by the difference in magnitude from prior to posterior probabilities, the greater the chances of a large research benefit.

Fourth, the value of research information is non-negative unless the research is wrong (or very costly in relation to its benefits). Therefore, while it easy to find that the research has no value because it did not influence a decision, it is much harder to obtain a negative result.

Fifth, the payoffs included in the examples provided are based on social gains or changes in aggregate economic efficiency as measured by rough estimates of economic surplus changes. The payoffs that the actual decision maker(s) considered might have included distributional concerns or other political objectives that only roughly correlate with efficiency. In the CPI case, revisions correcting bias may have been made in the name of a substantial gain in efficiency without adequate discussion of the distributional consequences.

The Bayesian decision theory approach is very useful for keeping the analyst focused on the essential issues that determine the value of AER research. Although one may need to interview 8-10 people to evaluate a particular case, one or two people provide the key probabilities and the others
provide context. We found ourselves making time-tradeoffs between the effort placed on obtaining probabilities and the effort placed on calculating payoffs to include in the model. Because there is a need for payoff estimates for each action/state pair, the calculations were undoubtedly less precise than they would have been had we focused all our efforts on estimating the benefits of the realized action/state or most likely action/state. Yet the sizes of the estimated payoffs affect the results just as much as the probabilities and so we felt uneasy about making the tradeoff. When Gardner prepared his analysis of the benefits of AER, he worked through a simple BDT example for research that estimated the elasticity of demand, never really using that result to estimate the benefits of research. Rather he reverted to simple economic surplus analyses, sans BDT, for the empirical part of the paper. The examples in this paper provide the first attempt to empirically use BDT with subjective probabilities to estimate the value of AER. Norton and Schuh conducted a similar analysis with “objective” probabilities using historical data, but unfortunately few research topics have such data.

References


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