IMPACT ASSESSMENT DISCUSSION PAPER NO. 6

POLICY FOR PLENTY: MEASURING THE BENEFITS OF POLICY-ORIENTED SOCIAL SCIENCE RESEARCH

George W. Norton and Jeffrey Alwang

Director General s Office

International Food Policy Research Institute
2033 K Street, N.W.
Washington, D.C. 20006
Tel: (202) 862-5600
Fax: (202) 467-4439
Email: IFPRI@CGIAR.ORG

December 1998

Little is known about the impact of social science research in general, and food policy research, in particular. In order to expand the scope of available academic research and to develop quantitative methods for estimating the impact of IFPRI's work, several papers were commissioned from social scientists. Furthermore, IFPRI held an essay contest to solicit research from a broader range of scientists. The resulting papers were discussed at a two-day symposium organized by IFPRI in 1997. This Discussion Paper is a revised version of a paper prepared for and discussed at the symposium. Other papers will be published in this Discussion Paper series over the next months.

CONTENTS

Page

LIST OF FIGURES

Page

ABSTRACT

This paper suggests practical methods for assessing policy research programs, both ex post and ex ante. Measuring the benefits of policy research is difficult: the path of causation between research and policy change is nearly always uncertain; multiple factors influence any particular policy change; policies are diverse in nature as are their intended and actual effects; and some effects of policy research are not priced in the market. Many of the benefits of changes in policy stem from the reduced cost of welfare-improving institutional change. Economic surplus analysis can be used to assess such changes. In some cases, Bayesian decision theory may be helpful in evaluating policy research, although it is usually difficult to obtain estimates of the probability distributions a decisionmaker has before the research becomes available. Subjective estimates of parameters and some measure of their degree of uncertainty, are likely to be needed for an economic surplus model. The paper suggests a set of steps for policy research evaluation. It is applied to two cases: an evaluation of pesticide policy research in Brazil, and an evaluation of policies affecting deforestation in Indonesia.

INTRODUCTION

Economists have made important contributions to understanding of the impacts of natural science and technology-oriented agricultural research. They have made fewer contributions to the understanding of the benefits of social science research, especially policy research. The need to evaluate policy research arises from two primary sources. First, as budgets tighten, public decisionmakers request more evidence of the impacts of research, including the impacts of policy research. Second, assessments of the value of policy research programs may help guide the allocation of resources to programs with the highest expected payoffs.

The purpose of this essay is to suggest practical methods for assessing policy research programs, both ex post and ex ante. It reviews the nature of the evaluation problem, draws lessons from previous attempts to assess social science research, and suggests an approach to evaluation, applying it to two examples of policy research. It stresses the importance of identifying the counterfactual, that is, what would have happened or will happen without the policy research, and addressing the uncertain nature of key parameters.

THE NATURE OF THE PROBLEM

Conceptually, the output of policy research is information. That information is usually imbedded in institutions. Many of the benefits of policy research stem from reductions in the cost of welfare-improving institutional change. In measuring the contribution of research to changes in policy, several issues are crucial. These include how to apportion credit among the many factors that affect a particular policy change, how to assess the causality between research and the implementation of a policy, and how to measure impacts that may not be reflected in the marketplace. Apportioning credit can be difficult because several pieces of research may contribute to a single policy change. Moreover, basic research on theory and methods contributes to the success of policy research and is part of the research cost, although it represents a fixed cost that is difficult to apportion among applied policy research programs. The more basic research is available, the lower the cost of designing better policies and the more likely it is that policy prescriptions will be correct.

Causality is an issue because it is difficult to ascertain whether an institutional change is due to social science research or to some other source. In other words, the question arises: what would have occurred without the policy research? It is easier to link a change in yield to plant breeding research than it is to link an institutional change to policy research.

The market fails to value the results of certain types of research aimed at technical change, but this problem may affect a higher proportion of the benefits of policy research. However, discovering ways to use markets to value as many of the results of policy research as possible is one of the keys to evaluating that research. Nonmarket assessment tools can be used, but only when the market value of the research cannot be determined.

The timing of policy research and the quality of data must also be considered. Timing is important because of the time value of money; advice offered after a decision is made can be worth little, and timeliness influences the likelihood that recommended changes will be adopted.

Demand for Policy Change

The demand for policy research is derived from the demand for institutional change (Ruttan 1984), even if that demand comes from groups motivated by self-interest rather than a desire to improve social welfare. Understanding the demand for a change of policy is particularly important when evaluating policy research ex ante. While one can observe whether policies have been adopted and measure their effects ex post, ex ante evaluations require estimation of the demand for a policy change and the likelihood that a new policy will be adopted. Key determinants of the demand for a policy change are the growth or decline of per capita income; changes in product and factor markets, including disequilibria in those markets; constraints on institutional change imposed by ideology, religion, and tradition; short-run political changes and budgeting pressures; and transactions costs and collective action. These issues must be considered case by case. For example, growth in per capita income can increase the demand for environmental amenities, but the value that a particular society places on those amenities needs to be measured empirically. As the demand for environmental amenities grows, so does the payoff to policy research that can influence them.

Changes or disequilibria in product and factor markets that result from technical changes, growth in population or income, or other sources can be major influences on the demand for institutional change (Schultz 1975, Ruttan 1984). Policies are changed to accommodate institutional stresses and strains brought about by disequilibria or secular changes in these markets. Policy research and extension can speed up institutional changes to accommodate such disequilibria. For example, as an economy develops, labor migrates from agricultural to nonagricultural employment. The result is that problems with income and adjustments in agriculture persist until late in the development process. These problems often create a demand for policies that address rural poverty but keep the price of food low to the growing urban population.

Ideology, religion, and tradition may reduce the demand for policy change (Ruttan 1984), while a change in political climate can stimulate it. The result is that the demand for policy research can be either constrained for long periods of time or ratcheted up rapidly.

Transaction costs, combined with the possibility for collective action, imply that the political power of different interest groups influences the direction of policy change

and the likelihood that a policy will be adopted. Transaction costs and collective action therefore influence both the distribution and the efficiency of policies. This influence makes an assessment of transaction costs and the strength of interest groups relevant to ex ante assessment of policy research.

The interaction among factors that influence the supply of and demand for institutional change determines the potential value of policy research. As market disequilibria, a growing divergence between private and social costs, and other factors increase the demand for research, the returns to such research also increase. An examination of factors contributing to the shifts provides clues about these returns. It is necessary to make such an examination in an ex ante evaluation. The presence of multiple social objectives also affects how policies are valued.

Multiple Objectives

Social science research can be designed either to influence the decisions of policymakers or to measure or change the behavior of economic agents such as producers and consumers. Policy-oriented social science research is clearly aimed at policymakers, whose decisions in turn influence the behavior of individual economic agents. Public officials use policy levers to address a variety of social objectives. Policy research may be needed to identify both the levers that can be used to address specific objectives and the advantages that particular policies may have over others.

A primary objective of agricultural research in most societies is to increase economic growth by improving agricultural productivity and efficiency. Policy research can contribute to this objective by improving allocative efficiency, reducing externalities that cause social costs to diverge from private costs, and reducing transaction costs that constrain economic growth. A second objective in many societies is to influence the income distribution to favor a particular group or factor of production. Policies can be potent tools for addressing such an objective, much more so than research that produces new technologies. Policy research can measure effects on distribution and provide information about how best to achieve such distributional goals. A third social objective is to reduce risk to health and safety, food security, prices, production, or income. Policy research has been aimed at the development of institutional mechanisms to efficiently reduce risk.

The presence of multiple objectives for policy increases the diversity in types of research conducted and complicates evaluation. It implies that it will be difficult to assess the aggregate benefits of policy research without identifying the types of policy research conducted or proposed and without explicitly identifying the objectives that the

policies are designed to achieve. This identification is also needed if the evaluation is to estimate the tradeoffs involved when particular objectives are targeted by policy research.

Lessons from Previous Evaluations of Social Science Research

The few previous quantitative evaluations of social science research have assessed the contributions of marketing, price analysis and outlook, or management research to increases in efficiency. The methods used have included economic surplus and econometric and decision theory approaches, sometimes in combination. Some studies have focused on how publicly provided information alters the behavior of producers. None has attempted to evaluate policy research, but some offer guidance about how one might approach such an evaluation.

Economic Surplus

The economic surplus approach has been used to evaluate the net benefits of more accurate outlook and price information (see, among others, Hayami and Peterson 1972; Bullock 1976; Freebairn 1976a, 1976b; Bradford and Kelegian 1977, 1978; and Norton and Schuh 1981). When producers estimate a commodity price to be above or below the equilibrium price, they produce a quantity that is larger or smaller than the equilibrium quantity. Research that leads to price forecasts closer to equilibrium reduces net social losses. The studies noted above derive expressions for calculating expected welfare effects on producers, consumers, and society as a whole. Freebairn (1976a, 1976b), for example, assumes that prices of agricultural commodities are formed rationally and compares perfect forecast prices to rational (but inaccurate) forecast prices in decisionmaking about supply.

One attraction of the economic surplus approach is that it generates measures of economic benefits that are directly comparable to the measures of benefit that have traditionally been generated for research on production. The approach may also have the benefit that the policy research itself may have calculated the potential surplus gains. A key question, however, is how to operationalize the surplus approach when addressing both uncertainty in the knowledge and beliefs of decisionmakers (producers, consumers, or public officials) and uncertainty found in additional parameters (such as causality or likelihood of policy adoption) required for the evaluation. Bayesian decision theory provides a possible method for placing a value on the information available to decisionmakers under these conditions.

Decision Theory

In Bayesian decision theory, learning takes place and modifies the probability distributions with which a decisionmaker starts. Such prior distributions can be assigned to all parameters wherever they appear in the model. Bradford and Kelegian (1977, 1978) and Norton and Schuh (1981) use Bayesian decision theory to evaluate information on the outlook and price of wheat and soybeans. They argue that the expected price is arrived at through Bayesian learning, but that learning results not only from observing market behavior but from information on the production outlook and prices. This information causes speculative inventory holders to revise their prior probability distributions. It also affects the commodity price distribution. These changes are evaluated using the economic surplus approach. The value of the information is the difference between maximum utility with outlook information and maximum utility without it. Bradford and Keligian (1978) used their model to forecast wheat crops in the United States. Norton and Schuh evaluate the soybean outlook information provided each year by economists from the University of Minnesota.

Uncertainty is summarized by the dispersion of the subjective probability distributions of individuals over possible states of the world (Hirschleifer 1973). Information consists of events tending to change these probability distributions.[1] One challenge in using decision theory is estimating the subjective probabilities before and after the new information is received. Norton and Schuh assumed that subjective prior distributions were based on historical probabilities of price movements for the preceding 15 years. Conditional probabilities were determined by comparing past outlook projections with the actual states that occurred. These probabilities were then used to calculate posterior probabilities using Bayes' formula.[2]

Lindner 1987 suggests that Bayesian decision theory should be applicable to policy evaluation as well. However, one problem in using it to evaluate policy research is the difficulty of obtaining estimates of priors from policymakers for the various states of nature. Unlike the situation where the decisionmakers are individual economic agents such as producers or consumers, market data cannot be used to estimate these prior distributions. Therefore subjective estimates would have to be elicited from the individual policy decisionmakers. While such elicitation is not impossible, it is clearly difficult, more so than eliciting prior distributions from producers for such variables as market prices. A second problem with this approach is in defining the states of nature for which prior expectations exist. It appears that direct application of Bayes' theorem to calculate the value of policy information will usually be difficult.

Econometric Approaches

Alternative procedures for valuing information that do not rely on Bayes theorem are suggested by Antonovitz and Roe (1985) for price uncertainty and by Roe and Nygaard (1980) for cases where the parameters of the underlying technology are not known with certainty. These procedures rely on the notion that producers base their allocation of resources on subjective estimates of prices and the underlying technology, and that these estimates are not entirely accurate. Information can be valued using "subjective" rather than "actual" or "more informed" production or profit functions. As with the decision theory approach, the value of information generated for an individual firm 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 were used by Norton (1987) to evaluate research and extension in farm management and marketing. However, the approach would be difficult to use to evaluate policy research because reductions in deadweight losses and success in meeting objectives other than increasing efficiency would be missed.

Simpler econometric approaches have also been used to evaluate farm management research. For example, farm management expenditures have been included as a separate variable, along with other research and extension variables, directly in a country-wide production or profit function model (see Evenson 1978). One can envision including a similar expenditure or publication-count variable (that is, the number of policy articles published) in such a model, but there would be many drawbacks to the approach.

First, policies are of many different types and are aimed at multiple objectives, so it is unlikely that using a policy variable in an aggregate profit function would produce a significant result. Estimates of production functions are not likely to be useful because policy research does little to shift the production function, except perhaps by influencing the rates at which technology is adopted. Policy research often effects movement along a given supply function; it does not shift the function itself. Also, one would like to measure the impacts of research on the achievement of each objective; a production or profit function approach usually only addresses the efficiency objective.

Second, many of the reductions in deadweight losses that come from reductions in policy distortions and externalities would be missed in such an approach, and reduction in allocative errors are obtained by factors other than policy research. Third, it would be difficult to use cross-sectional data because most policies spill across geographic areas. Time-series data are limited in many developing countries. Fourth, it would be difficult to specify what should be included in a policy variable. For example, should macroeconomic policies be included? If one included a broad set of policies in a

publication count, using, say, a cross-country data set, the analysis would miss key costs involved in a policy dialogue, and the variable would not provide a link to the cost of the research. In other words, even if one did estimate a cross-country production function and picked up a significant effect of a policy variable, it would be difficult to link the effect back to research and there would be legitimate concern that the significance would only be spurious. In addition, such an aggregate analysis would not help an evaluation of specific policy research programs or the allocation of resources among types of policy research. The preceding points do not argue against using econometrics to measure parameters affecting changes in surplus. They do suggest that an aggregate econometric analysis of the benefits of policy research will be uninformative.

Previous social science evaluation efforts show that an aggregate econometric approach is not likely to help much, and direct application of Bayesian decision theory to the evaluation of policy is difficult. The latter is particularly hampered by the difficulty of estimating the prior distributions of the decisionmakers directly influenced by policy research, public officials and bureaucrats. However, the decision theory approach highlights how important it is to incorporate uncertainty in the evaluation. The multiplicity of policy objectives and types of policies dictate a disaggregated assessment of individual policies or classes of policies. Disaggregation of the impacts of policies by societal objectives may be necessary as well. Such a need to disaggregate suggests that it would be appropriate to adopt a case study approach using economic surplus as a measure of welfare changes.

The economic surplus approach, despite its well known deficiencies, is likely to be the starting point for policy research evaluation, as it can incorporate subjective estimates of parameters and generates results that can be compared both with each other and with results from evaluations of production-oriented research. Such an approach allows for ex ante or ex post evaluations of a portfolio of research projects. The section that follows presents a possible framework.

A FRAMEWORK FOR MEASURING THE BENEFITS OF POLICY RESEARCH

The evaluation of policy research requires an assessment of the value of policy changes. It also requires, for ex post assessment, a determination of the contribution of policy research to those changes and, for ex ante assessment, an estimation of the likelihood that a proposed policy change will be adopted. Several steps must be undertaken in the evaluation, whether it is done ex post or ex ante. First, the problem must be defined in terms of the objectives of the evaluation, the policy research programs to be evaluated, objectives for the policies, and the path followed from the research to the change in policy (actual or projected). Formulae must be defined for measuring

economic benefits. An illustrative list of programs, a policy path, and examples of how benefits might be measured for various types of policy programs such as marketing, credit, labor, and research are provided in Norton and Alwang (1997).

Second, market data (such as prices, quantities, and elasticities) and other data needed for research must be compiled. Estimates must be made of potential changes in costs, the likelihood that a policy will be implemented, lags in research and implementation, and so on. For ex post evaluation, the policy research itself may have already supplied some of this information. If not, it may be necessary to elicit people's subjective estimates. Such subjective estimates are needed for all ex ante evaluations.

For ex post analysis, an attempt can be made to talk to people involved in the policy decision to determine the influence of the research. There is likely to be a tradeoff between the time and cost spent locating and interviewing people and the quality of the evaluation. For ex ante analysis, it may be possible to assess historical probabilities for factors such as the adoption of a policy in order to place rough bounds on future probabilities. For example, the probabilities that results of research will be adopted may be lower when they call for land reform than when they call for changes in price policy. It may be useful to ask policymakers or staffers how large the total benefits must be before the opposition of interest groups can be overridden.

Uncertainty of parameter estimates argues that information should be gathered in a way that will allow for a distribution around those estimates. For simplicity, a triangular distribution can be used for key parameters such as the probability of a policy being adopted or the probability that research contributed to an observed policy change (Anderson, Dillon, and Hardaker 1977; Alston, Norton, and Pardey 1995).

The third task is to analyze the data by combining the data and the formulae for economic surplus derived to assess specific policy research, applying capital budgeting methods to the streams of benefits and costs, and then using the results to help justify programs or choose among alternatives.

The fourth task is to use and interpret the results. If internal rates of return (IRRs) are calculated for the policy research program, they can be used to assess the merits of the investments and to compare them with alternative public investments. The net present values can be used to create rankings to help with decisions about resource allocation.

Agricultural policies often have distributional objectives. If the policies evaluated have such objectives, it can be useful to assess whether they are being met and to determine the opportunity cost in terms of the total benefits of the policy research program that are sacrificed if benefits are skewed toward specified groups.

The two examples given below help illustrate the feasibility of the method. The first example, policy research on deforestation in the Brazilian Amazon, was chosen because the problem affects the entire world and the information is in the public record. The second example, tax and exchange rate policies influencing pesticide prices in the Philippines, is an example of an evaluation of research with benefits that must be projected into the future. Both examples are merely illustrative, as key parameters were obtained from fewer sources than one would normally use for such analyses.

MEASURING BENEFITS FROM POLICY RESEARCH: POLICIES ASSOCIATED WITH DEFORESTATION IN THE BRAZILIAN AMAZON

The accelerated deforestation that has occurred in the Brazilian Amazon represents an important area of policy research that began to be addressed in the early 1980s. LANDSAT satellite imagery that became widely available at that time showed that deforestation began in the 1960s following construction of highways such as the one that runs from Brazilia to Belem. This deforestation accelerated sharply in the 1970s, raising concern about its impacts on the local and global environment. Anecdotal evidence indicated that part of the deforestation stemmed from policies that encouraged the expansion of the agricultural frontier, and research began looking at the links between policy and deforestation.

Studies by Browder (1985), Binswanger (1991), Mahar (1989), and researchers at the Brazilian agriculture research agency EMBRAPA found that agricultural and economic policies created distortions that led to the inefficient expansion of agriculture and uneconomic logging. Binswanger and Mahar categorized some of the policies that created these distortions.

Agricultural income was largely exempt from federal taxation, which created incentives to engage in agriculture as a means of sheltering other income. Policies for land allocation and titling ensured that squatters were granted titles. Titles were normally given for up to three times the amount of the land that was cleared. Land taxes declined with the intensity of use of the land, and forested land was considered to be unused. These tax rules created incentives for uneconomic forest clearing since pasture was considered an intensive land use; by converting forest land to pasture, tax liabilities declined. Agricultural credit policies were linked to deforestation through the need for land title to secure loans. Titling was made conditional on “land improvements.” In practice this meant clearing the land. These tax and credit policies created indirect incentives for additional land clearing and increased the demand for farmland (Binswanger 1991; Mahar 1989). Pan-territorial pricing of inputs and fuel subsidies

contributed to inefficient expansion of agriculture to remote areas. The pricing policies also increased the demand for farmland.

In addition to indirect incentives, direct tax incentives were provided for livestock development projects by the Superintendencia do Desenvolvimento da Amazonia (SUDAM), the regional development agency for the Amazon. The incentives were originally designed to support industrial development, but eligibility was expanded to include agricultural projects. By 1985, SUDAM had approved 950 projects for tax credits; 631 of these were for livestock development (Mahar 1989). Several authors have noted that without tax credits, livestock development had a negative real rate of return (Binswanger 1991; Browder 1985)[3] and concluded that the SUDAM incentives were directly responsible for as much as 10 percent of total deforestation in the Brazilian Amazon. Other tax credits encouraged deforestation; Binswanger and Mahar examined the effects of these credits and their impacts on deforestation in detail. This completed policy research can be used as an example of how to evaluate policy research aimed at an environmental issue with global implications.

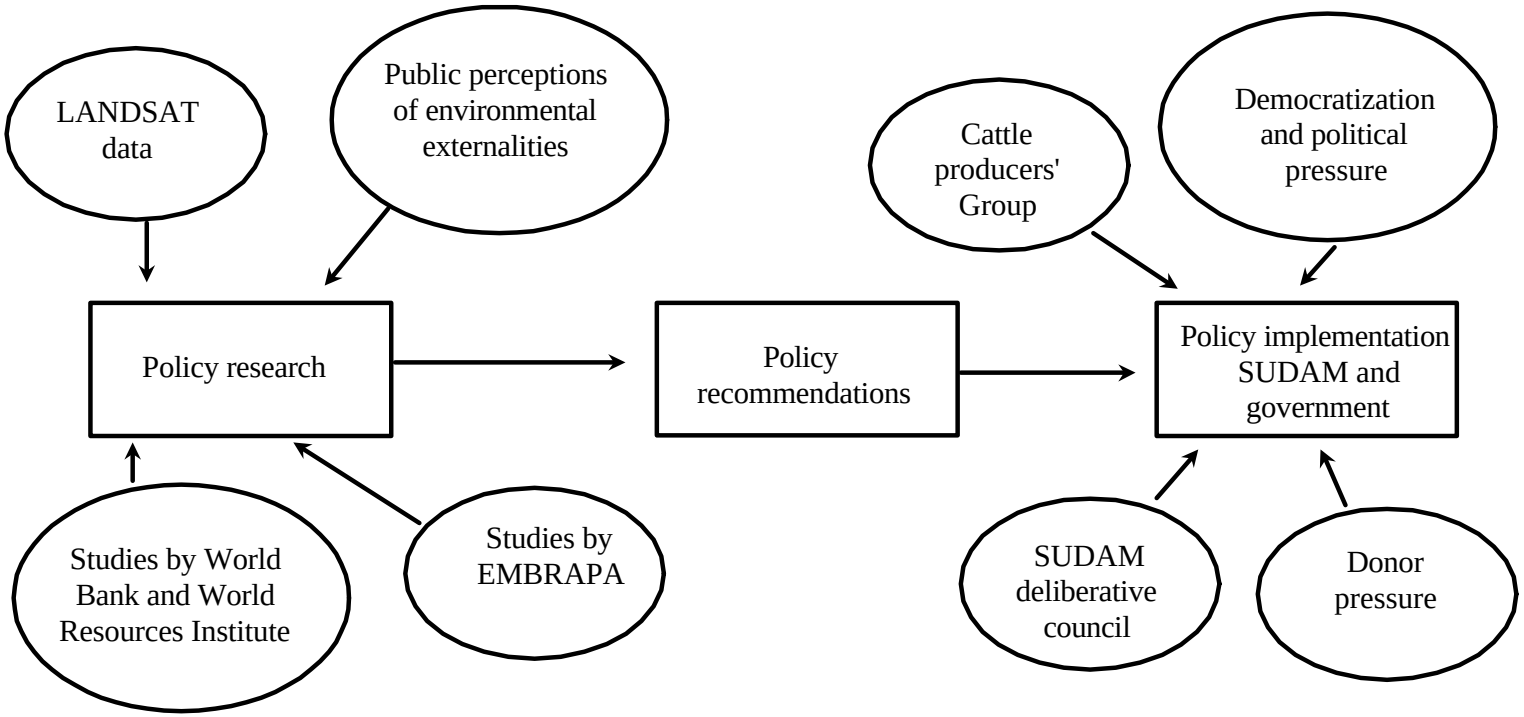
Defining the Problem

The objective for this evaluation of policy research is to determine, ex post, the benefits from the research on policies affecting deforestation of the Brazilian Amazon. The objective of the original research was to determine how the policies contributed to the misallocation of resources by creating incentives for uneconomic deforestation. The researchers also suggested ways to reform the policies. The policies themselves had multiple objectives. These included increasing settlement in outlying areas to relieve population pressures in other parts of the country and expanding the agricultural frontier.

The value of research can be considered by tracing the effects of research findings on policy decisions: How were policies changed as a result of the research and what was the value of these changes? To do this, evidence is needed on how deforestation was affected by the policy changes and how much of the policy change was itself due to the research findings.

The path the policy research followed began with a public perception of a disequilibrium and led to the ultimate outcome, a change in the offensive policies (Figure 1). The critical steps in conducting the evaluation are, first, to measure the benefits of the change and, second, to determine what portion of the policy change is attributable to the research.

Figure 1—Path for Amazon policy research

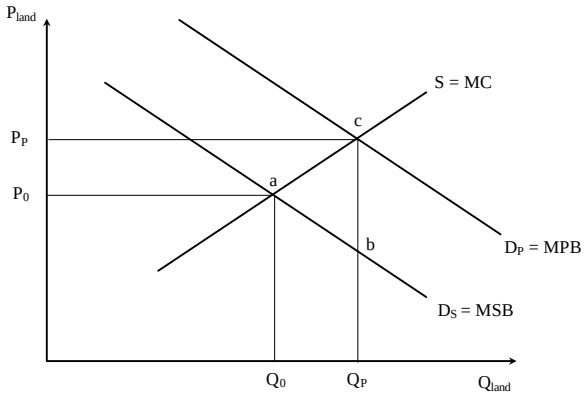


Defining How the Benefits Will Be Measured

There are at least two alternative markets where benefits from the research could be measured: the product market (mostly beef, but other alternatives such as lumber exist) and the factor market (land). Nonmarket valuation techniques can also be used. The studies suggest that deforestation was largely a by-product of the demand for farmland and pasture, and that this demand was stimulated by the policies. It thus becomes convenient to measure the effects of the policies through their effect on the market for land. The policy-induced distortions affect the land market by shifting the demand for and supply of farmland away from their social optima.

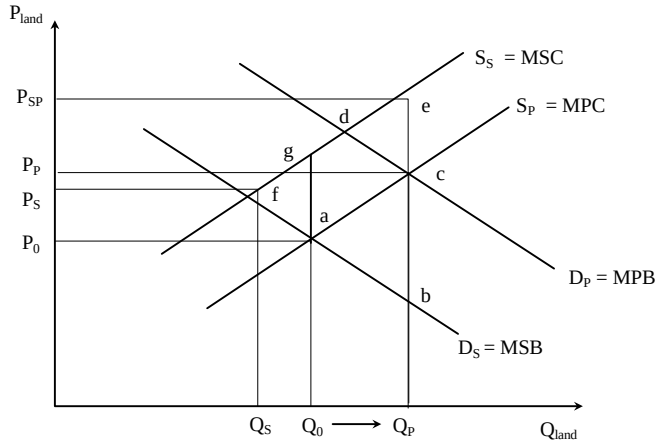
The socially optimal demand schedule for cleared land in Brazil reflects the marginal social benefits associated with an increase in farmland. The "private" or market demand (reflecting the marginal private benefit schedule) diverges from the social benefit schedule because of policies such as direct subsidies, tax credits, and income tax exemptions. These policies increase the demand for cleared land above its optimum for society, raising the equilibrium price and quantity. By raising the equilibrium price, the policies are said to be capitalized into the price of land. Such capitalization leads to some of the equity effects discussed by Binswanger. The effects of the policies are shown in Figure 2. Private demand (D_p) is found to the right of socially optimal demand (D_s). Q_0, P_0 would have prevailed in the market, but the policies lead to a greater equilibrium quantity (Q_P) of cleared land and price (P_P) of land. The loss to society resulting from the policy is represented by the triangle *abc*; this triangle is a deadweight loss incurred by taxpayers. This deadweight loss can be thought of as the "cost" to society of achieving other objectives, such as slower population growth in cities. In order to measure the amount of the deadweight loss, equilibrium quantities and prices need to be known, as must the elasticities for land supply and demand and the amount of the shift in demand induced by policy.

Figure 2—Land market effects of policies that encouraged use of farmland and pastures in Brazilian Amazon



Measurement of the deadweight loss from the policies is complicated by the external costs associated with deforestation. Most of the policy analyses examined implied that these costs were significant, but did not measure them explicitly. These costs include off-farm costs from soil erosion and siltation, on-farm costs incurred because of reductions in soil quality that result from this erosion,[4] carbon loading in the atmosphere owing to burning of the felled forest, a loss of biodiversity, and the option value associated with the loss of rainforest. These externalities cause the marginal social cost associated with the supply of cleared farmland to diverge from the private cost curve. In Figure 3, the private equilibrium (which is observed in the market) occurs at point *c*, with quantity Q_p and price P_p. The social optimum occurs at point $f\ (Q_s, P_s)$. The deadweight loss associated with the policy distortions given the externalities would be the triangle *ebf*. When the policies are removed, the equilibrium price and quantity will be found at point $a\ (P_0, Q_0)$, since social costs still diverge from private costs. The surplus change from removal of the subsidy is area *abeg*. This is the measure of benefits from policy research.

Figure 3—Externality effects of clearing farmland in the Brazilian Amazon



The divergence between social and private marginal costs must be considered in calculating benefits, because even though a policy does not shift the marginal social cost curve, the amount of the benefits from the policy change will be affected by these externalities (see Figure 3). When such externalities are present, the measured benefits of policy research depend on the focus of analysis. If, for example, the focus is on the benefits to residents of Brazil, external costs would be measured only as they are incurred by Brazilians. The share borne by Brazilians of the total global costs of carbon loading in the atmosphere, biodiversity preservation, and maintenance of rain forest for option or use will be substantially lower than global social costs.

The formula for measuring the change in surplus is as follows.[5] Referring to Figure 3, define

$$K = (c \quad b)/P_p, \text{ and}$$
$$K' = (e \quad c)/P_P$$

The total change in economic surplus would then be

$$CTS = 0.5KP_p(Q_p \quad Q_0) + K'P_p(Q_p \quad Q_0)$$

This formula is used in the analysis below.

Compiling the Data

The data are taken from a number of sources. The equilibrium price of land, taken from Ozorio de Almeida and Campari (1995), was US$219.[6] This price is from sample surveys and is representative of average land prices in the legal Amazon (Schneider 1995).

A minimum estimate of the divergence between marginal private costs and marginal social costs of deforestation is used (this is the distance *ce* in Figure 3). The minimum value of carbon sequestration per hectare of Amazonian rainforest is estimated to be $272,[7] and the minimum value of the cost associated with maintenance of biodiversity is estimated to be $20 per hectare (this is a lower-bound estimate obtained by synthesizing information found in Pearce and Moran 1994). Without including local external costs associated with loss of soil quality, siltation, and so forth, the minimum estimated social cost is $292 per hectare. This yields an external cost of $73 per hectare ($292 – $219).

The distance *bc* in Figure 3 is computed using historical data on subsidies and deforestation. Mahar cites LANDSAT data showing that between 1970 and 1988, 569,000 square kilometers (km^2) had been deforested. Between 1987 and 1988, approximately 23,100 km^2 were deforested. This gives a total of 545,900 km^2 deforested from 1970 to 1987 (World Resources Institute 1994). During this time, approximately $3,704.3 million in subsidies was provided to approved projects and farmers in the region.[8] The subsidy for land clearing was thus $67.86 per hectare ($3,704.30 ÷ $54.59).

The Effects of Research on Policy Change

The effects of research on Brazilian policy cannot be understood in isolation. During the late 1980s, there was considerable public pressure for changes in policy to protect the environment, and stronger pressure for a more open political process. The military dictatorship ended with the formation of the New Republic in 1985, and José Sarney, the president until 1990, began institutional changes that were, on the surface,

friendly to the environment. The 1989 constitution contained an entire chapter dedicated to the environment. It has been called the most advanced text for environmental protection in the world. Included in the constitution is a declaration that the legal Amazon (which includes approximately 445 million hectares) is an area of national heritage. Policies associated with deforestation began to be examined as the public increased pressure for environmental protection. Many of the offending policies have since been changed.

Three researchers — Browder, Binswanger, and Mahar — were interviewed to gain insights into the effects of the research on policy changes. Three basic questions were asked; the responses are summarized below.

The first question was: "How have policies related to inefficient land clearing for cattle ranching been changed?" The respondents, and other sources, indicated that SUDAM began to enforce a moratorium on subsidies to cattle ranches by the late 1980s, and that all direct fiscal subsidies for cattle ranching were eliminated by 1992. National tax laws were reformed in the early 1990s, closing the loophole that allowed agricultural income to be exempted from federal taxes. Credit programs have been reformed to a lesser extent, but their contribution to total demand for ranch land is probably now negligible. Input pricing reforms were undertaken.

The second question was: "In your estimation, how much deforestation would have occurred had the policies not changed?" There was a consensus that deforestation has continued. Recent evidence is that cattle ranching may not be as uneconomic as early authors concluded. Schneider (1995) shows that much of the Amazon ranch population consists of smaller establishments that probably did not take advantage of the direct subsidies. Hecht (1993) notes that the current high rates of deforestation are largely associated with a dynamic that may have started with the subsidies for large ranches, but has now taken on a life of its own. Deforestation may have been jump-started by policy errors, but its solution is now more complicated. Estimates are that removing the policies have reduced deforestation about 15 percent.

The third question was: "How much influence did the research have on the policy change? That is, had the policy research not occurred, what is the likelihood that the policy change would have occurred anyway?" Browder was uncertain about the role of policy and suggested referring to the minutes of the Deliberative Council of SUDAM. Binswanger noted that his research was widely disseminated in 1987. For instance, his paper was reprinted in the *Journal de Brazil*. He told the authors that "it was deeply influential in the World Bank as well, and the emphasis on policy reform to reduce deforestation was integrated into Bank doctrine." None of the researchers was willing to attach a quantitative estimate to the proportional influence of the research on changes in

policy. Secondary sources suggest that policy research made up about 10 percent of the influence in the decisions to change the policies. This is a rough estimate, however, and is subjected to sensitivity analysis in the calculations below.

Analyzing the Data

It is estimated that 0.6 percent of the Amazon area is being deforested annually (World Resources Institute 1994). The total estimated area of the Brazilian Amazon is 445 million hectares (Schneider 1995). Deforestation, therefore, consumes about 2.31 million hectares per year. If removal of the policy reduced deforestation about 15 percent per year, this change would preserve about 346,000 hectares of forested land. Therefore, $Qp \quad Q_0$ = 346,000 in Figure 3. This number can be combined with external costs (*ec*) ($73 per hectare), the per-unit subsidy (*bc*) ($67.86 per hectare), the estimate for the policy contribution (10 percent), and the economic surplus formula to calculate the benefits of the policy research. The loss in surplus avoided because of the policy change can be estimated for the 15-year period, between 1992, by which time most of the policy change had occurred, and 2007. A 5 percent discount rate is used and the net present value of benefits calculated.

By these calculations, the total discounted surplus loss that would be avoided because of policy research is estimated to be approximately $42 million. The external costs associated with deforestation account for about 68 percent of the surplus loss; deadweight losses (excluding social costs) from the policies average about $11.7 million per year. The social losses are incurred by all citizens of the world (recall that the costs associated with atmospheric carbon loading are used here to measure the social costs). The $11.7 million per year are losses to Brazilians alone. Because no information was gathered on the costs of the research, no rate of return can be calculated.

Sensitivity analysis can be performed to test the importance of the 10 percent assumption for the contribution of the research to the policy decision. Because the nondiscounted benefits are equal each year, the variables in the spreadsheet are related multiplicatively, and research costs are not considered, the benefits would simply be halved if the 10 percent assumption were halved. This would put them at $21 million over 15 years at the 5 percent discount rate.

Interpreting the Results

Policy research on Amazon deforestation appears to have earned high returns with major international spillovers even if the research only had a small effect on a decision to change policy. This example shows that many environmental policies are like public goods, clearly justifying the research support provided by the World Bank and the World

Resources Institute. The example illustrates how returns to policy research can differ sharply, depending on whose perspective is used to perform the analysis. The appropriate costs to include in assessing the benefit of the policy research will depend on this perspective as well.

MEASURING BENEFITS FROM POLICY RESEARCH: PESTICIDE POLICIES IN THE PHILIPPINES

Several studies in recent years have indicated that pesticides are overused in Philippine rice and vegetable production (for example, see Rola and Pingali 1993; Antle and Pingali 1994; Pingali and Roger 1995; Lazaro et al. 1995). To remedy this situation, the Philippine government has (1) empowered its Fertilizer and Pesticide Authority (FPA) to ban or otherwise regulate pesticides, (2) set up an advisory committee to the FPA to make recommendations on pesticide policy, and (3) established integrated pest management (IPM) programs in rice and vegetables. IPM programs appear to hold the greatest long-term promise for reducing pesticide use while increasing producer profits, but the adoption of IPM practices depend in part on their profitability compared to the use of pesticides.

Pesticide prices in the Philippines are influenced by tax and subsidy policies. Therefore a vegetable IPM project in the Philippines recently conducted an analysis of the direct and indirect pricing policies that affect pesticides used on vegetables to predict whether current policies constrain the adoption of IPM practices, and, if they do, to provide information to the FPA and its advisory committee as they make and implement pesticide policies. Evaluating this completed research project provides an example of how policy research on pricing and environmental policies can be assessed. Each of the components of evaluation identified in the conceptual framework presented above is included in this example.

Defining the Problem

The objective of the evaluation is to estimate the net present value of the vegetable-pesticide policy research project, undertaken by Tjornhom (1995) and others, in order to demonstrate the feasibility of such an estimation. The research to be evaluated was focused, but included price analysis, macroeconomic analysis and environmental policy analysis. The major direct policies that the pesticide policy project assessed were import tariffs and value-added taxes. The Philippine government used both of these to raise revenues and reduce incentives for pesticide use. The major indirect policy assessed was an overvalued exchange rate. This policy put downward pressure on inflation and subsidized both producers who used imported inputs and consumers. It also inadvertently

and indirectly subsidized an input, pesticides, that creates an environmental externality. The policy research led by Tjornhom was designed to reduce any policy-induced environmental externality.

The pesticide policy research drew upon previous economic studies such as Intal and Power (1991) who calculated the amount of the subsidies or taxes on several agricultural commodities in the Philippines during the 1980s. The research benefited from discussions with officials of the FPA, pesticide company representatives, Department of Agriculture personnel, and economists on the agribusiness support project funded by USAID and from data they provided. The pesticide policy research itself was funded under the USAID-supported IPM Collaborative Research Support Program (IPM CRSP), which supports collaborative research among the Philippine Rice Research Institute, U.S. universities, the University of the Philippines – Los Baños, and the International Rice Research Institute. It took 18 months to produce the findings of the research. Researchers have since exchanged views about policy with a member of the pesticide advisory committee, FPA, and others (Figure 4). The policy recommendations derived from the research came close on the heels of a separate research project on rice that was aimed at assessing the effects of pesticides on the health of farmers and the implications of those effects had for policy.

The vegetable-pesticide policy project found that the nine primary pesticides used on vegetables in the Philippines received subsidies of approximately 6 percent based on a net direct tax of about 12 percent and an indirect subsidy due to the overvaluation of the exchange rate of 18 percent. The project recommended that direct pesticide taxes (tariff and value-added taxes) be maintained and that the government follow policies that reduce the overvaluation of the Philippine peso. No decisions about the recommended policies have yet been made. This evaluation of the policy research, therefore, is partly ex post and partly ex ante.

Defining How the Benefits Will Be Measured

The vegetable-pesticide policy research could show several net benefits. Environmental externalities might be lower than they would be if the direct taxes on pesticides were reduced or removed. There could be a gain in efficiency and reduced environmental damage if the exchange rate became less overvalued. But there might also be losses in efficiency due to the tax. More IPM practices could be adopted, lowering the marginal social cost curve associated with vegetable production.

Figure 4—Path for pesticide policy research

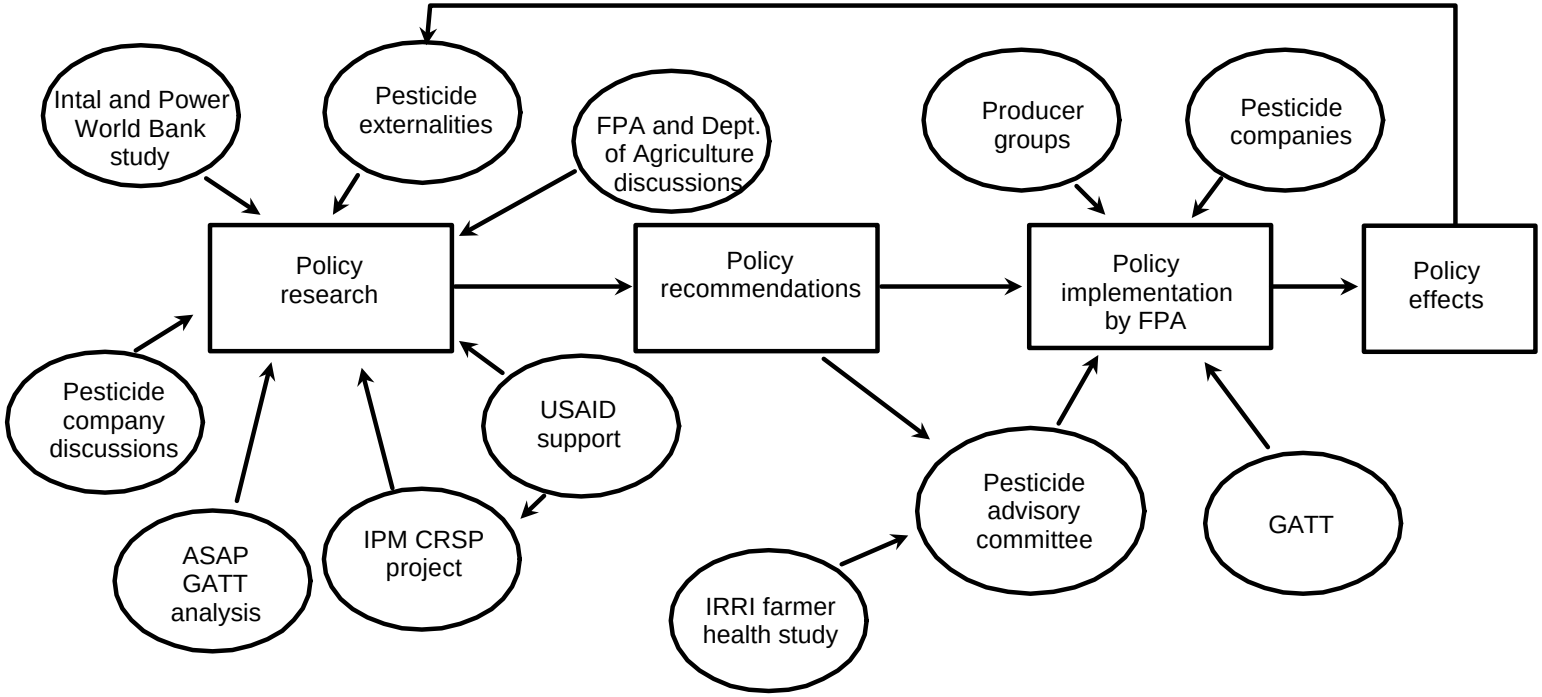
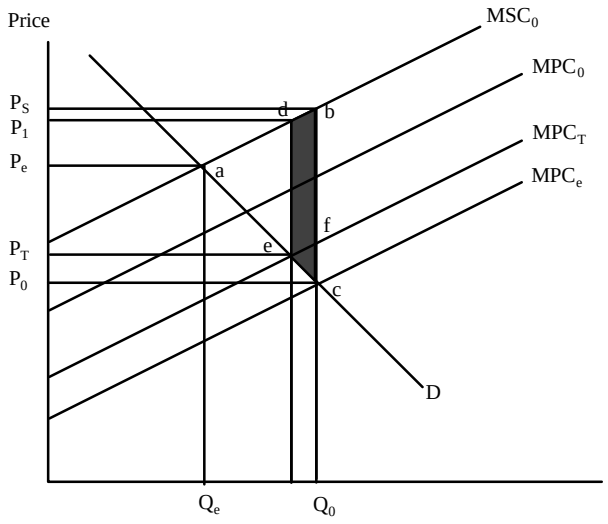


Figure 5 presents a model of the retail pesticide market for the nine pesticides monitored in the analysis.[9] The marginal private cost of supplying the pesticides, not including any taxes or exchange rate overvaluation that subsidize the imported active ingredients in the pesticides, is represented by MPC_0. The marginal social cost curve with no taxes or exchange rate effects is MSC_0. This lies above MPC_0 because of the social (environmental and health) costs associated with the pesticides. The effect of the overvalued exchange rate is to increase the social costs, shown by the shift from MPC_0 to MPC_e. The tariff and value-added tax on pesticides (and active ingredients) reduce the social costs, in effect shifting MPC_e back to MPC_T. The research on pesticide policy estimated the vertical distance between MPC_e and MPC_T to be about 12 percent of the retail price (P_T).

Figure 5—Measuring the marginal social cost of pesticide taxes and subsidies



It appears that the policy research is not likely to influence the overvaluation of the exchange rate, though it recommended that the overvaluation be reduced. The actual exchange rate and the equilibrium free market rate differ because of a broad set of policy distortions rather than a single overt policy action. It can be assumed, therefore, that the research can only influence direct tax policy. The net social benefits from maintaining the current tax policy, as recommended by the research, rather than reducing the taxes on pesticides can be measured as area *abc ade = dbce* minus the efficiency loss due to the policy distortion (*efc*). The net benefits, considering both the environmental and efficiency effects, would be *abc ade efc = dbfe*.

In the long run, the development and adoption of IPM practices would reduce the marginal social cost of vegetable production by reducing the use of pesticides. This effect could be modeled either as a downward shift of the marginal social cost curve of vegetable production or as a reduction in the demand for pesticides. Because the net effect of current tax policy on IPM adoption is likely to be small, it will be ignored in the present evaluation. Therefore the pesticide policy evaluation will focus on measuring *dbfe*, which can be measured by the formula:

$$CTS = P_T Q_T Z n K^t,$$

where

CTS	=	change in total economic surplus,
Q_T	=	pesticide quantity with an overvalued exchange rate and taxes in place,
P_T	=	pesticide price with an overvalued exchange rate and taxes in place,
K^t	=	per unit marginal social cost of pesticides as a proportion of P_T,
K	=	per unit direct tax as a proportion of P_T,
Z	=	$Ke/(e+n)$ = proportionate reduction in price from P_T to P_0,
n	=	absolute value of the price elasticity of demand for the pesticides, and
e	=	price elasticity of supply for the pesticides.

Derivation of this formula makes use of the fact that $Q_0 = Q_T (1 + Zn)$.

Compiling the Data

Data on quantities and prices for the nine pesticides analyzed in the policy research are presented in Tjornhom (1995). For the evaluation, the data on total quantity and weighted average price can be used. These are calculated to be 254,291 kilos and 253 pesos or $10.50 per kilo. Given the current absence of alternative pest management practices, the demand for pesticides is likely to be inelastic. Supply, on the other hand, is likely to be elastic as more active ingredients can be imported as needed, subject to short-run constraints on capacity in the Philippine plants that formulate the pesticides. Tjornhom (1995) estimated the demand elasticity to be –0.5 and the supply elasticity to be around 1.0. These estimates may underestimate the elasticity of supply but is used in the evaluation below. The research estimates the proportionate direct tax to be 12 percent of P_T.

The difference between the marginal social cost associated with pesticide use and the marginal private cost may be the most difficult item to estimate. Such an estimate

will have to be made using secondary sources of information because it would take a separate research project to get it from primary sources such as contingent valuation surveys or hedonic methods. Expert opinion is also a questionable source. Pingali, Marquez, and Polis (1994) assessed the effects of insecticide use on health costs and found that those costs increased by roughly a half percent for each percent increase in the dosage of insecticide applied. That was enough to offset any profits earned by the farmer in applying the pesticide to rice. This figure does not include the costs of chronic health problems or other environmental effects. While it is more profitable to use pesticides on vegetables than on rice, it is difficult to estimate the marginal social cost of applying the pesticides. It seems reasonable to begin with a conservative estimate of the marginal social cost. Alternative assumptions about that cost can be introduced later. The differences in the returns to policy research that they produce can be assessed using sensitivity analysis. For the analysis below, the marginal social cost of pesticides is assumed to be 20 percent of the average price of the pesticides. The effect of reducing this assumption to 10 percent will be examined later.

Because the research has just been completed and the results not yet adopted, it is necessary to gather expert opinion on the likelihood that its recommendations will be implemented and about what the time lag in that implementation might be. If possible, three or more people knowledgeable about the policy issue should be interviewed. For this example only two people were interviewed. They were asked four sets of questions.

The first was "What is your most likely estimate (percent probability) that the direct taxes on pesticides will be maintained by the Philippine government decisionmakers, as recommended in the pesticide policy report. What is your lowest likely estimate? Highest probability estimate? Why?"

The respondents gave 70 percent as the most likely estimate, 20 percent as the lowest, and 100 percent as the highest. The most likely estimate was based on the assumption that an economist on the pesticide advisory committee might carry the recommendation to the government. Also, there is increasing public pressure to reduce the health effects of pesticides. While the pesticide industry lobbies to remove the taxes, farmers usually do not recognize that the pesticide price has the tax included, so they have not protested the tax. Also, the tax generates revenue for the government.

To the second question, "How long is it likely to take for adoption (an explicit policy decision) to occur?," the respondents gave an answer of two years.

The third question was "What is your most likely estimate (percent probability) that the tax policy would have been maintained irrespective of the research? Lowest likely estimate? Highest probability estimate? Why?"

The answers of the respondents were 60 percent for the most likely estimate, 20 percent for the lowest, and 70 percent for the highest. Pressure is already on the government to reduce the environmental and health effects of pesticides, and, again, the tax generates revenue.

Lastly, the respondents were asked "When do you believe that sufficient IPM practices will be available for and adopted on vegetables so that use of the identified pesticides will decline, irrespective of tax/subsidy policy?" They gave 10 years as their answer.

Data on policy research costs are also needed, as is a discount rate to use in capital budgeting. Research costs in this example are easy to estimate because the project is focused on particular policies; the costs of research do not have to be apportioned over multiple objectives. Approximately $40,000 was spent over 18 months on personnel, travel, data collection, supplies, communications, administration, and so forth. An additional $5,000 is likely to be spent on fostering a dialogue about the policies at issue. The real discount rate is estimated to be 5 percent.

Analyzing the Data

The data generated as described above and the formula used to calculate the economic surplus can be incorporated in a spreadsheet to calculate the net benefits from the policy research project. The spreadsheet includes a triangular probability distribution showing the probability that a policy will be adopted. A Monte Carlo simulation is used to generate a distribution of values for economic surplus, net present value, and IRR. Incorporating the uncertainty of the parameters in this way provides a confidence interval around the expected value. A simpler approach to the evaluation would be to average the low, medium, and high values for the parameter for policy adoption in order to obtain its expected value for use in the analysis. That approach could be used if a large number of programs were being evaluated and an analysis were needed more quickly.

For the current study, the triangular distribution approach was used as described by Anderson, Dillon, and Hardaker (1977, 268–269). Two hundred uniform variates were generated and included in the equations. These variates were used to generate the triangular distribution for the policy adoption variable (see Norton and Alwang 1977 for details). The 200 estimates of the probability of policy adoption were then included in the economic surplus equation, so that 200 estimates of net present value and IRR were calculated. The mean for net present value was $134,203 with a 95 percent confidence interval of $11,017.[10] The mean value of the IRR was 29 percent with a 95 percent confidence interval of 1.5 percent.

The 29 percent rate of return is at the low end of the range often cited in studies of research evaluation. However, the assumptions used in the present analysis may be conservative, especially the assumption that tax policy only affects the nine most important pesticides used on vegetables. Rates of return for specific projects can be expected to vary greatly with few projects and programs having high payoffs and several that yield little. One purpose of ex ante evaluation is to increase the proportion of high returns in the policy research portfolio.

Due to the uncertainty of the 20 percent assumption for the marginal social cost of pesticides, the benefits were recalculated using a 10 percent assumption. This change reduced the estimated mean net present value to $48,726 with a 95 percent confidence interval of $5,509 and an estimated IRR of 16 percent.

Interpreting the Results

While it is only a simplified example, the pesticide policy research evaluation illustrates the feasibility of evaluating policy research projects using the economic surplus approach. A similar approach could be used for a portfolio of possible policy projects or programs. It becomes even more important for such an evaluation to incorporate the risk component in various parameters and to conduct the evaluation assuming two or three alternative levels of funding for each program as discussed above. The pesticide policy research evaluation did not calculate the effects of the policy recommendations on the distribution of the benefits, but it would not be difficult to do so.

CONCLUSIONS AND IMPLICATIONS

Measuring the benefits of policy-oriented social science research is difficult for a number of reasons. The diversity of types and objectives of agricultural policies requires, at a minimum, an analysis that is disaggregated by major type of policy. Causality between completed policy research and changes in policy is nearly always uncertain. Predicting the adoption of policy recommendations is highly uncertain in the ex ante evaluation of policy research. The complexity of the effects of policy usually implies that evaluation is forced to use approximate measures lest the evaluation of each policy research program or project become a major policy research project itself. Lastly, certain types of policy research generate benefits that are not priced in the market.

These difficulties render any aggregate econometric analysis of the benefit of policy research highly suspect, but do not preclude the use of economic surplus analysis. Bayesian decision theory may be a useful approach for valuing information provided by certain types of social science research programs, especially where they affect the

decisions of individual economic agents whose prior distributions can be estimated using market data. However, decision theory is difficult to apply in policy analysis aimed at government decisionmakers because of the difficulty of assessing the prior distributions of policymakers.

Economic surplus analysis has the advantage that it can facilitate evaluation of diverse types of policies, assess the distributional effects of policy research, generate results that are directly comparable to evaluations of technology-oriented research, calculate ex post or ex ante research benefits, and provide an assessment that is consistent with economic theory. In some cases, the surplus measures may be rough, but the more such evaluations are completed, the shorter will be the learning curves for those attempting them in the future.

The uncertain nature of many of the parameters used in an evaluation of policy research dictates a need for carefully structured questions posed face-to-face with those most knowledgeable about the policy process and the proposed or completed research. Ex post analysis or historical documents can provide benchmarks or guideposts for certain parameters in some cases, just as it does (or should) in evaluations of technology-oriented research. However, the inevitable uncertainty of the parameters used in policy-oriented social science research makes it especially important to use distributions around those parameters and to conduct analysis that generates confidence intervals. Sensitivity analysis for key parameters is also recommended.

For ex ante analysis, learning something about the severity of disequilibria in the affected markets and the political costs of policy changes can help to predict whether recommended policies will be adopted and the value of the research. The greater the disequilibria in resource use, the greater the potential gains from relieving the policy or other institutional constraints causing the disequilibria. An excellent example is the large efficiency gains in Chinese agriculture that followed the change in its property rights system and other changes in policies after 1978. It is no coincidence that the fastest growing economies in the world are poor. Lower-income countries are farther from reaching their economic potential than wealthier countries. Thus, when a poor country can reduce institutional constraints that cause economic disequilibria, its growth can take off (Olson 1996).

The political costs of making a decision can greatly affect the odds that policy advice will be followed. Those costs are influenced by the political power of interest groups. This, in turn, is influenced by the cost of collective action. The latter depends in part on the size and homogeneity of interests of the groups, with small homogeneous groups often exercising substantial power. Also, the larger the potential total benefits associated with a policy change, the greater the likelihood that it will be adopted.

Understanding why a society adopts its policies is crucial for predicting whether a proposed piece of policy research will change them. Fortunately, a large body of literature has developed on why policy change occurs in agriculture (for example, see Anderson and Hayami 1986 and Roe and Pardey 1991). However, there should be no illusions about the difficulty of making a quantitative evaluation of policy research ex ante. The uncertainty surrounding the estimated benefits of such an evaluation will inevitably be high.

It is clear that policy changes almost always depend on multiple factors, including multiple policy studies. Apportioning credit among the factors is difficult, but not impossible in most cases. For ex post analysis, it can be helpful to examine the extent to which the policy research was fed into a policy dialogue with decisionmakers. Even good applied policy research often ends up only in journals, with little or no influence unless the policy dialogue was explicitly pushed.

Modeling the market effects of policies graphically and in formulae for economic surpluses is important. But the most difficult aspect of an ex post evaluation of policy research is gathering information that allows a careful assessment of possible counterfactual outcomes (what would have happened to the supply and demand curves without the research?). The most difficult aspect for an ex ante evaluation is assessing the probability that policy recommendations will be adopted. Despite these difficulties, it appears that quantitative evaluations of policy research are feasible using carefully structured economic surplus analysis if the methods include means for considering the uncertainty of the parameters.

NOTES

This is a condensed version of a paper presented at the Symposium on Measuring the Benefits of Policy-Oriented Social Science Research, April 5, 1997, at the International Food Policy Research Institute, Washington, D.C.

1. The decision theory approach can be summarized as follows: A variety of actions $(a_1, a_2 \quad Y.a_m)$ are open to the decisionmaker. Several states of nature $(S_1, S_2 \quad S_n)$ are also possible. The decisionmaker has some knowledge of the likelihood (prior probability) of such states occurring, $P(S_i)$. With a given amount of knowledge, the decisionmaker will choose the action, a_I, that maximizes his or her expected utility. The expected utility of the j^{th} action is $\Sigma_i u\,(a_j\, S_i)P(S_i)$. Now if additional information $(Z_1, Z_2 \quad Z_m)$ becomes available to the decisionmaker and he or she has knowledge of the probability of the information coming true, that is, $P(Z_jS_i)$, by Bayes theorem, $P(S_iZ_j) = P(S_i)P(Z_jS_i) / \Sigma_i P(S_i)P(Z_jS_i)$. The revised expected value of a_j is now $\Sigma_j u(a_jS_j)P(S_iZ_j)$. The value of information is the difference between the maximum utility with and without the information. This can be compared with the cost of obtaining the information.

2. They also assumed that the utility function was linear, so that maximizing expected profits was equivalent to maximizing expected utility.

3. Recent evidence (Schneider 1995) shows that cattle ranching may not be as uneconomic as early authors concluded. Schneider shows that many ranches were smaller establishments that probably did not receive direct subsidies. Distorting incentives other than direct subsidies (for example, titling procedures) , however, did benefit even these smaller establishments, so that the policies stimulated the demand for farmland.

4. This cost can be considered an externality because of poor information on the part of the soil user/owner of the land.

5. In many cases, it is necessary to derive the formula in terms of one existing quantity (say Q_p). In the present case, estimates have been made of $Q_p \quad Q_0$ in the policy analysis and this can be used in the analysis, removing the need for elasticities.

6. All values are in 1991 U.S. dollars.

7. This value is based on the estimate of 16 tons of carbon for the average hectare in the legal Amazon found in Fearnside (1992), and low estimate of $20 per ton of

costs from global warming damage found in Fankhauser (1994). This figure is close to the $245 minimum estimate by Schneider (1995) in a range that goes up to $28,300 per hectare.

8. These data are taken from Schneider 1995 (Table 1.3). They assume that 4 percent of livestock credit went to the Northern Region and a subsidy of $364.4 million for 1970. Dollar figures were inflated from US$ 1990 to US$ 1991 using a 3 percent inflation rate.

9. The market can be modeled as a closed economy because almost all pesticide imports come in as active ingredients that are not traded, but formulated into pesticides for use domestically.

10. This confidence interval assumes that only the probability of adoption is uncertain. Of course, this procedure could have been followed with triangular distributions around other parameters as well, and a joint probability distribution and confidence interval developed.

REFERENCES

Alston, J. M., G. W. Norton, and P. G. Pardey. 1995. *Science under scarcity: Principles and practice for agricultural research evaluation and priority setting*. Ithaca, NY: Cornell University Press.

Anderson, J. R., J. L. Dillon, and J. B. Hardaker. 1977. *Agricultural decision analysis.* Ames, Ia: Iowa State University Press.

Anderson, K., and Y. Hayami. 1986. *The political economy of agricultural protection*. Sidney, Australia: Allen and Unwin.

Antle, J. M., and P. L. Pingali. 1994. Pesticides, productivity, and farmer health: A Philippine case study. *American Journal of Agricultural Economics* 76 (3): 418–430.

Antonovitz, F., and T. Roe. 1985. A producer's willingness to pay for information under price uncertainty: Theory and application. *Southern Economic Journal* 52 (2): 382–391.

Binswanger, H. P. 1991. Brazilian policies that encourage deforestation in the Amazon. *World Development* 19 (7): 821–829.

Bradford, D. F., and H. H. Kelegian. 1977. The value of crop forecasting in a market system: Some theoretical issues. *Review of Economic Studies* 44: 519–531.

_____. 1978. The value of crop forecasting with Bayesian speculation: Theory and empirical results. *Bell Journal of Economics* 9: 123–144.

Browder, J. O. 1985. Subsidies, deforestation, and the forest sector in the Brazilian Amazon. Report to the World Resources Institute, Washington, D.C.

Bullock, J. B. 1976. Social costs caused by errors in agricultural production forecasts. *American Journal of Agricultural Economics* 58 (1): 76–80.

Evenson, R. E. 1978. A century of productivity change in U.S. agriculture: An analysis of the role of invention, research, and extension. Center Discussion Paper No. 296. Economic Growth Center, Yale University, New Haven, Conn.

Fankhauser, S. 1994. The social costs of greenhouse gas emissions: An expected value approach. *The Energy Journal* 15 (2): 157–184.

Fearnside, P. M. 1992. Forest biomass in Brazilian Amazonia: Comments on the estimate by Brown and Lugo. *Intersciencia* 14 (6): 291–297.

Freebairn, J. W. 1976a. The value of distribution of the benefits of commodity price outlook information. *Economic Record* 52 (June): 199–212.

_____. 1976b. Welfare implications of more accurate national forecast prices. *Australian Journal of Agricultural Economics* 20 (2): 92–102.

Hayami, Y., and W. Peterson. Social returns to public information services: Statistical reporting of U.S. farm commodities. *American Economic Review* 62 (1): 119–130.

Hecht, S. B. 1993. The logic of livestock and deforestation in Amazonia. *Bioscience* 43: 687–695.

Hirschleifer, J. 1973. Where are we in the theory of information? *American Economic Review* 63: 31–39.

Intal, P. S., and J. H. Power. 1991. The Philippines. In *The political economy of agricultural pricing policy.* Vol. 2: *Asia,* ed. A. O. Krueger, M. Schiff, and A. Valdés. Washington, D.C.: The World Bank.

Lazaro, A. A., K. L. Heong, B. Canapi, V. Gapud, and G. W. Norton. 1995. Farmers' pest management knowledge, attitudes, and practices in San José, Philippines: A baseline survey. IPM CRSP Working Paper 95-2. Virginia Polytechnic Institute and State University, Blacksburg, Va.

Lindner, R. 1986. Toward a framework for evaluating agricultural economics research. Presidential address, Australian Agricultural Economics Society, Adelaide, Australia.

Mahar, D. J. 1989. Deforestation in Brazil's Amazon region: Magnitude, rate, and causes. In *Environmental management and economic development,* ed. G. Schramm and J. J. Warford. Baltimore, Md.: Johns Hopkins University Press.

Norton, G. W. 1987. Evaluating social science research in agriculture. In *Evaluating agricultural research and productivity*, ed. W. B. Sundquist. Miscellaneous Publication 52-1987. Minneapolis, Minn.: University of Minnesota, Agricultural Experimental Station.

Norton, G. W., and J. Alwang. 1997. Policy for plenty: Measuring the benefits of policy-oriented social research. Staff Paper SP-97-6, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University, Blacksburg, Va.

Norton, G.W., and G. E. Schuh. 1981. Evaluating returns to social science research: Issues and possible methods. In *Evaluation of Agricultural Research*, ed. G. W. Norton et al. Miscellaneous Publication 8-1981. Minneapolis, Minn.: University of Minnesota, Agricultural Experimental Station.

Olson, M., Jr. 1996. Big bills left on the sidewalk: Why some nations are rich and others are poor. *Journal of Economic Perspectives* 10: 3–4.

Ozorio de Almeida, A. L., and J. S. Campari. 1995. *Sustainable settlement in the Brazilian Amazon*. New York: Oxford University Press.

Pearce, D., and D. Moran. 1994. *The economic value of biodiversity*. London: Earthscan Publications.

Pingali, P. L., and P. A. Roger. 1995. *Impacts of pesticides on farmer health and the rice environment*. Norwell, Mass.: Kluwer Academic Publishers.

Pingali, P. L., C. B. Marques, and F. G. Palis. 1994. Pesticides and Philippine rice farmer health: A medical and economic analysis. *American Journal of Agricultural Economics* 76 (3): 587–592.

Roe, T., and D. Nygaard. 1980. *Wheat, allocation error and risk, northern Tunisia.* University of Minnesota Economics Development Center Bulletin 5. Minneapolis, Minn.: Economics Development Center, University of Minnesota.

Roe, T., and P. G. Pardey. 1991. Economic policy and investment in rural public goods: A political economy perspective. In *Agricultural research policy: International quantitative perspectives,* ed. P. G. Pardey, J. Roseboom, and J. R. Anderson. Cambridge: Cambridge University Press.

Rola, A. C., and P. L. Pingali. 1993. *Pesticides, rice productivity, and farmers' health: An economic assessment*. Los Baños, Philippines: International Rice Research Institute.

Ruttan, V. W. 1984. Social science knowledge and institutional challenge. *American Journal of Agricultural Economics* 66 (5): 549–559.

Schneider, R. R. 1995. Government and the economy on the Amazon frontier. Environment Paper No. 11. World Bank, Washington, D.C.

Schultz, T. W. 1975. The value of the ability to deal with disequilibria. *Journal of Economic Literature* 13 (3): 827–846.

Tjornhom, J. D. 1995. Assessment of policies and socioeconomic factors affecting pesticide use in the Philippines. M.S. thesis, Virginia Polytechnic Institute and State University, Blacksburg, Va.

World Resources Institute. 1994. *World resources, 1994-95: A guide to the global environment*. New York: Oxford University Press.

George W. Norton and Jeffrey Alwang are professors in the Department of Agricultural and Applied Economics at the Virginia Polytechnic Institute and State University, Blacksburg, Virginia, U.S.A.