AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Miscellaneous Publication 8--1981
Minnesota Agricultural Experiment Station
University of Minnesota

Evaluation of Agricultural Research

Proceedings of a Workshop Sponsored by NC-148
Minneapolis, Minnesota May 12-13, 1980

EX ANTE EVALUATION OF THE SEPARATE EFFECTS OF RESEARCH AND EXTENSION1/

Yao-Chi Lu*

Introduction

Much research work has been conducted in recent years to evaluate the effects of research and extension.2/ Some of these efforts were conducted at the national aggregate level, while others were conducted at the regional or community levels. The methodologies used in those studies varied, but most of the studies were based on regression analysis of ex post data.

There are several difficulties associated with the above ex post analyses. First, the time lags from the time of research resource commitment to production of extendable technology (invention), i.e., the leadtime, ranges from a few years to decades. It is difficult to collect time series data to accommodate a long leadtime. Besides, the average leadtime is not known unless one studies specific research projects. Thus, most, if not all, researchers ignore the leadtime. They just assume that research output will come about as soon as the research resources are committed, even though most researchers recognize and account for adoption lag.

Secondly, research and extension enter into the process of technological innovation at different points in time. Although feedbacks from extension often result in changes in the direction or additional research to be conducted, extension plays little role in the development of a new technology. When the research is completed and a new technology is produced, extension comes into play. Thus, extension follows research in that process. Many researchers recognize this lag, but unless dealing with a specific technology, the lag length is usually unknown.

Thirdly, in time series data, research and extension expenditures are highly collinear. One reason for the existence of this collinearity is that the budgets are allocated or authorized for both functions regarding the same issue at the same time. Attempts to estimate the separate effects of research and extension using the regression analysis often fail.

Fourthly, all ex post analyses were based on data since World War I when fossil fuel was cheap and abundant. Since the likelihood of having cheap and abundant fossil fuel in the future is very slim, the estimated relationships may not be relevant in predicting or planning for the future.

This study proposes an alternative approach to overcome the above difficulties. The purpose of this study is to describe proposed methodology and procedures to estimate the separate rates of return to research and extension in U.S. agriculture using an ex ante analysis.

The Process of Technological Innovation

The process of technological innovation starts with an idea or confrontation of a problem and ends with widespread adoption of the technology throughout an industry or a market. This process can be divided into two periods: (1) the creation of a new technology and (2) dissemination of this technology.

During the first period, after an idea is initiated and resources are committed to conduct research, a theory is proposed to solve the problem and experiments are conducted to confirm the validity of the proposed theory. When the first primitive model or the prototype of a new technology (which can be a new product or a new process) is developed, it is tested in the laboratory and later tried under field conditions. If the field trials prove to be successful, a new technology is created. During this period of research, resources are committed, but no extendable technology is created. Thus, no effects on productivity can be felt. The length of this period, a leadtime, varies from one technology

*Evaluation and Impact Staff, Joint Planning and Evaluation, Science and Education Administration, U.S. Department of Agriculture. The views expressed here are those of the author, and do not necessarily reflect the position of the Science and Education Administration or the U.S. Department of Agriculture.

to another. Increased research resources provide scientists more support and equipment and thus shorten the leadtime.

In the second period, a new technology is ready for commercial introduction. This is when time extension comes into play. During this period, extension agents are busy teaching farmers the new technology and conducting field demonstrations. Initially, only a small number of farmers adopt the technology because the possible payoff of the new technology is uncertain and the potential early adopters need time to learn how to use the new technologies.

As early adopters benefit from using the new technology, more and more farmers will be attracted to it. As a result, the percentage of adoption increases exponentially. Eventually, as most potential adopters adopt the new technology, the percentage of adoption will level off and approach a maximum. For the purpose of this study, the period between the commercial introduction to the time the percentage of adoption reaches the maximum is called an adoption lag. The length of adoption lag also varies with different technologies. With increased funding for extension, it is possible to shorten the adoption lag and/or increase the percentage of adoption.

The above technological innovation model is a simplified one. In reality, the dividing time for the two periods is not clear cut. Furthermore, even before the completion of research, some information about the new technology is diffused to farmers. Rosenbert (1976, p. 76) observes that:

> Innovation is, economically speaking, not a single well-defined act but a series of acts closely linked to the inventive process. An innovation acquires economic significance only through an extensive process of redesign, modification, and a thousand small improvements which suit it for a mass market, for production by drastically new mass production techniques, and by the eventual availability of the whole range of complementary activities, ranging, in case of the automobile, from a network of service stations to an extensive system of paved roads.

That is, a single technological breakthrough that may consist of many minor technologies developed over a period of years. For example, the first substantial commercial-scale application of research results on hybrid corn did not occur until the thirties, although serious research on hybrid corn began early in the century (Mansfield 1966, p. 122). In 1906, G. H. Schul, a geneticist at Cold Spring Harbor, New York, started experiments on heredity in corn (Sprague 1962, p. 106). Many state and federal inbreeding and hybridization programs were started in the early twenties. By 1921, the first commercial, double-cross hybrid, Burr-Leaming, was released and recommended by the Connecticut Agricultural Experiment Station. Hybrid corn technology has involved almost continuous developments of new hybrids. Thus, there has been a considerable overlapping of leadtime and adoption lag.

For simplicity, the first substantial large-scale introduction of a technology is considered a dividing time for the two periods.

Procedures

To obtain information needed to estimate the separate rates of return to research and extension, we plan to conduct a mailed Delphi survey and to hold two Delphi workshops. The Delphi technique is a systematic procedure for eliciting and collecting information from a panel of "experts". Two major characteristics which are distinct in the Delphic technique are feedback and anonymity (Linstone and Turoff, 1975). During the "Delphi Exercises", information from the summary of the responses is fed back to the experts for review. Each expert may contribute more information or take a different position. Through iterative processes of evaluation and re-evaluation, a consensus can be reached.

The most commonly used Delphi is a paper-and-pencil version. In this process, a questionnaire is mailed to the experts. After the questionnaire is returned, the responses are collated and the summary of the group's responses is fed back to the experts for re-evaluation. Another form of Delphi is a Delphi conference or workshop where the group's responses are processed by a computer programmed to carry out the compilation of the group results. Thus, the summary of the group's responses can be fed back to the experts immediately for re-evaluation.

In conducting a Delphi study, special attention should be given to the procedures used in selecting experts to ensure selection of an unbiased panel possessing expertise in the required areas. Bregman, Katz, and Salasin (1977) identified several possible problems which might be encountered in selecting experts to serve on the Delphi panel and provided useful guidelines to solve the problems.

To minimize delays in mailing questionnaires back and forth to the experts and to reduce the cost of holding long workshops, this study proposes to use a combination of one mailed Delphi and two workshops.

Identification of Emerging Technologies

Based on past studies and literature review, we will compile a preliminary list of emerging

technologies, the background information, and experts on the technologies which could have unprecedented impacts on agricultural production and productivity in the next 50 years. Then, a questionnaire will be developed and mailed to 50 scientists for additions to and modifications of the list. Through Delphi processes, the technologies which could produce unprecedented impacts on agricultural production, resources use and the environment will be selected.3/

A Workshop On Emerging Technology

About 30 agricultural scientists having expertise in future agricultural technologies will be invited to participate in a four-day Delphi workshop. The participants include specialists in specific future technologies and some "generalists."

Prior to the workshop, the list of emerging technologies and their background information will be distributed to all participants. For each future technology, a lead scientist will be selected and asked to prepare a short, nontechnical statement about the technology--what it is, areas of research, the probable year of commercial introduction, crops and livestock that will be affected, how it will affect productivity, and the effect on resource use, environment, and size of farms.

The lead scientists will present this information at the beginning of the workshop to stimulate thinking and discussion. The current and recent funding of research for each technology also will be provided to the participants.

For each technology, the panel of scientists will be asked to identify the affected crops and livestock and to estimate the effect on agricultural production (yields, livestock reproductive and feeding efficiency, etc.), resource use, and environment from the introduction and adoption of the technology. Under the assumption that recent trends in research funding for these technologies will continue into the future, the panel of scientists will be asked to estimate the year that a given technology will be introduced. Then they will be asked how much additional research funding will be needed to speed up the introduction of a given technology for a specific number of years.

Delphi Workshop on Technology Adoption

About 20 extension specialists will be invited to participate in a three-day workshop to estimate an adoption profile for each unprecedented technology identified in the previous workshop. Prior to the workshop, each participant will be given a list of technologies along with background information about the technologies. The information includes description of the technology, how it affects crop and livestock production, and the profitability and capital requirements for adopting the technology.

Under the assumption that current extension budget for disseminating new technologies continue into the future, the panel will be asked to estimate the length of adoption lag (from commercial introduction to the time the maximum percentage of adoption is attained), the percentage of adoption, and factors which impede adoption. With increased funding for extension, the panel will be asked to estimate how many years the adoption lag can be shortened and how much the percentage of adoption can be increased. Through Delphi processes, a consensus about the estimates can be obtained. Based on the information from the workshop, the adoption profiles (S-shaped curves) will be estimated for each technology.

Contributions of Research and Extension

As discussed above, research and extension enter to the process of technological innovation at different points of time, but they are complementary. Research results must be disseminated and adopted by farmers to affect agricultural productivity. Extension activity helps speed up the adoption process and increase the percentage of adoption. Thus, the effect of a given technology on agricultural productivity depends on the level of extension activity. On the other hand, the effectiveness of extension depends upon the effectiveness of research. Without research, no new knowledge can be extended by extension agents. Therefore, research and extension are interrelated and complementary. To estimate the separate contribution of research and extension, we rely on the partical analysis, i.e., holding extension at a certain level while we estimate the contribution of research. Likewise, in estimating the contribution of research, the level of extension is held constant.

The Rate of Return to Research

Suppose a given set of research resources is invested in the production of a particular technology in time 0 and the research is completed and a new technology is successfully developed in time m. During this period. research resources R_{1t} (t = 0, 1,...., m) are invested in each time period.

At time m, extension comes into play. As indicated earlier, the percentage of adoption is assumed to increase along an S-shaped growth curve as shown in Figure 1. At time n, the percentage of adoption reaches a maximum. The adoption lag is n - m.

If additional research resources are invested to provide scientists more support and equipment

in development of this research, the leadtime can be shortened from m to m'. The research expenditures invested during this period are R_{2t} ($t = 0, 1, \ldots, m'$; $m' < m$). With the same level of extension activities, the adoption curve shifts from A_1 to A_2. The difference in the adoption profiles due to additional research expenditures is shown in Figure 2.

Introduction of a new technology may affect many commodities. For example, enhancement of photosynthetic efficiency may be applicable to soybeans as well as corn, sugar beets, sorghum, and many other crops. Let A_{1jt} be the percentage of adoption of the technology on the jth commodity at time t (i.e., t-m years after commercial introduction) before investing additional research expenditures, a_{2jt} the percentage of adoption after investing additional research expenditures, v_j the net increase in the value of producing the jth commodity when the technology is wholly adopted. Then, the net increases in the values of producing the jth commodity at time t before and after additional research investments are, respectively,

$$V_{1jt} = a_{1jt}v_j$$

and

$$V_{2jt} = a_{2jt}v_j$$

Thus, the marginal income increase in the value of producing the jth commodity at year t due to added research investment is

$$V_{2jt} - V_{1jt} = (a_{2jt} - a_{1jt})v_j$$

Since research and extension enter into the process of technological innovation at different points of time, to compute the rate of return to investment in research involves comparison of benefits received and costs incurred at different periods. Suppose we want to compute the ex ante rate of return at time m' when the research with increased level of expenditures is just completed. To be comparable, the costs incurred in the past (from time 0 to time m') must be compounded, while the benefits expected to receive in the future (from time m' to time n) must be discounted to present values.

Let C be the sum of the stream of additional investment in research compounded at the rate of r percent annually to the year m' and B_j the present value of the sum of the stream of future marginal returns for the jth commodity, then

$$C = \sum_{t=0}^{m'} (R_{2t} - R_{1t})(1 + r)^{m'-t} - \sum_{t=1}^{m-m'} R_{1t}/(1+r)^t$$

and

$$B_j = \sum_{t=0}^{n-m'} (V_{2jt} - V_{1jt})/(1 + r)^t$$

The total marginal returns for the P commodities are

$$B = \sum_{j=1}^{P} B_j = \sum_{j=1}^{P} \sum_{t=0}^{n-m'} (V_{2jt} - V_{1jt})/(1 + r)^t$$

Therefore, the marginal internal rate of return (r) to research can be obtained by solving the following equation for r:

$$\sum_{j=1}^{P} \sum_{k=0}^{n-m'} (V_{2jt}-V_{1jt})/(1+r)^t - \sum_{t=0}^{m'} (R_{2t}-R_{1t})(1+r)^t - \sum_{t=1}^{m-m'} R_{1t}/(1+r)^t = 0$$

The Rate of Return to Extension

In estimating the contribution of extension on agricultural production, the level of research expenditures is held constant. By varying the level of extension expenditures, the marginal contribution of extension can be estimated. Let E_{ijt} be the extension expenditures spent on disseminating the jth new technology in year t with i=1 denoting before and i=2 after investing additional expenditures.

An increase in extension activities can either increase the percentage of adoption, or shorten the adoption lag, or both. Figure 3 illustrates the case where increased extension expenditures increase the percentage of adoption for any given time, but the length of adoption lag and the maximum percentage of adoption remained unchanged. In the second case, shown in Figure 4, an increase in extension expenditures increases the percentage of adoption at any given time and the maximum percentage of adoption, but the length of adoption lag remains the same. In the third case (Figure 5), an increase in extension expenditures shortens the adoption lag but the maximum percentage of adoption remained unchanged. In the fourth case, an increase in the extension expenditures increased the percentage of adoption as well as shortens the length of adoption lag (Figure 6). In either case, the marginal contribution of extension on the jth commodity at a given time t is measured by the product of the net increase in the value of producing the jth commodity (v_j) and the vertical distance between the two adoption profiles ($a_{2jt} - a_{1jt}$):

$$V_{2jt} - V_{1jt} = (a_{2jt} - a_{1jt})v_j$$

The present value of the total increase in extension expenditures for the ith commodity is

$$C_j = \sum_{t=0}^{n-m} (E_{2jt} - E_{1jt})/(1 + r)^t, \text{ for cases 1 and 2}$$

and

$$C_j = \sum_{t=0}^{n'-m} (E_{2jt}-E_{1jt})/(1+r)^t - \sum_{t=n'-m}^{n-m} E_{1jt}/(1+r)^t, \text{ for}$$

cases 3 and 4

The present value of the total increases in extension expenditures for all the commodities are

$$C = \sum_{j=1}^{P} C_j$$

The internal marginal rate of return to extension (r) can be obtained by solving the following equation for r

$$\sum_{j=1}^{P} \sum_{t=0}^{n-m} (V_{2jt} - V_{1jt})/(1 + r)^t - \sum_{j=1}^{P} C_j = 0$$

Figure 1. A Change in the Year of Commercial Introduction Due to Increased Research Expenditures.

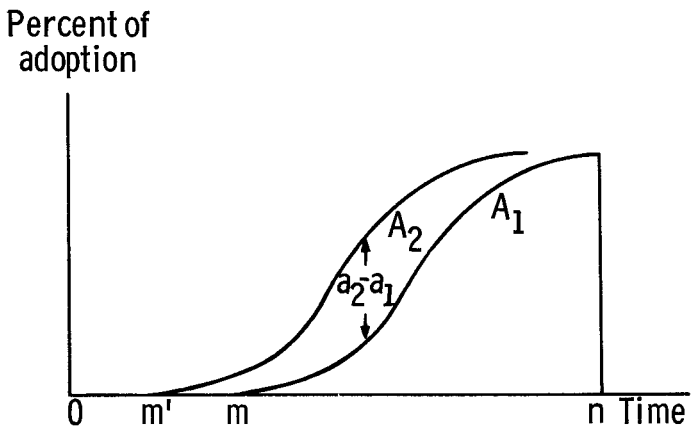


Figure 2. A Change in the Percentage of Adoption Due to Increased Research Expenditures

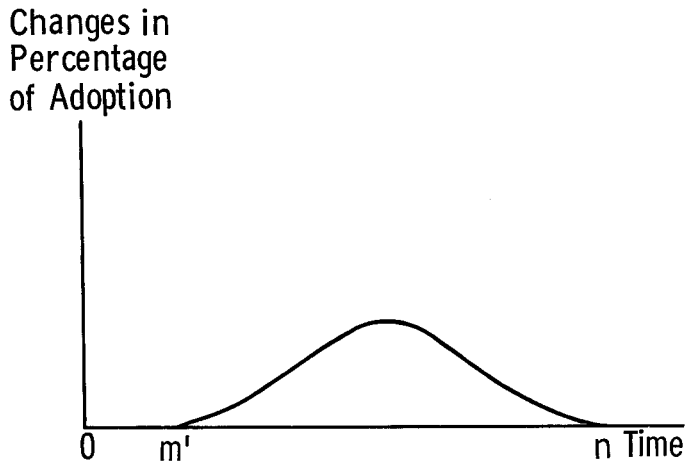


Figure 3. A Change in the Percentage of Adoption Due to Increased Extension Expenditures.

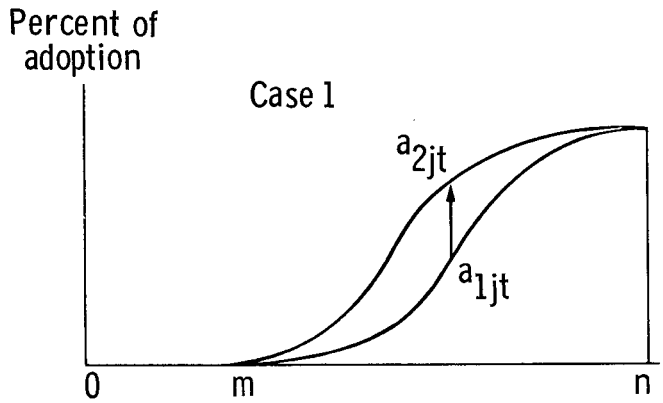


Figure 4. A Change in the Maximum Percentage of Adoption Due to Increased Extension Expenditures

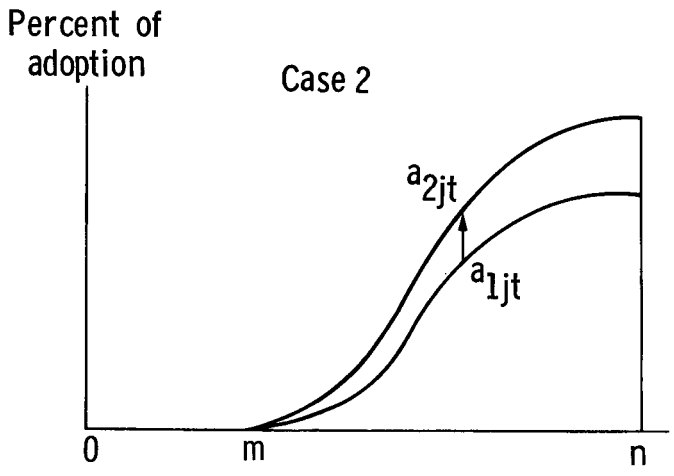


Figure 5. A Change in the Adoption Lag Due to Increased Extension Expenditures.

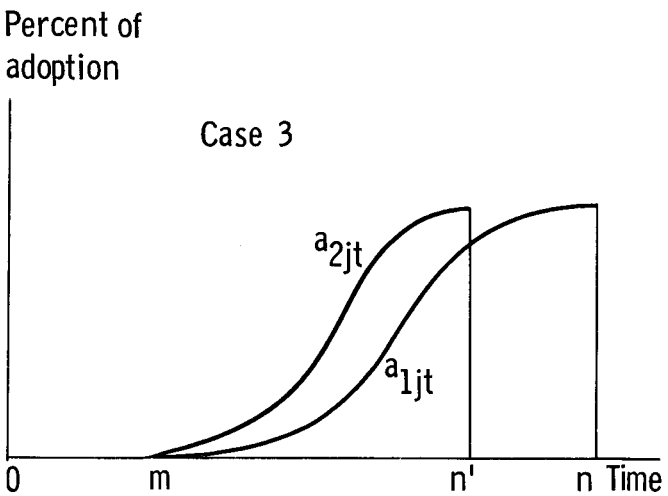
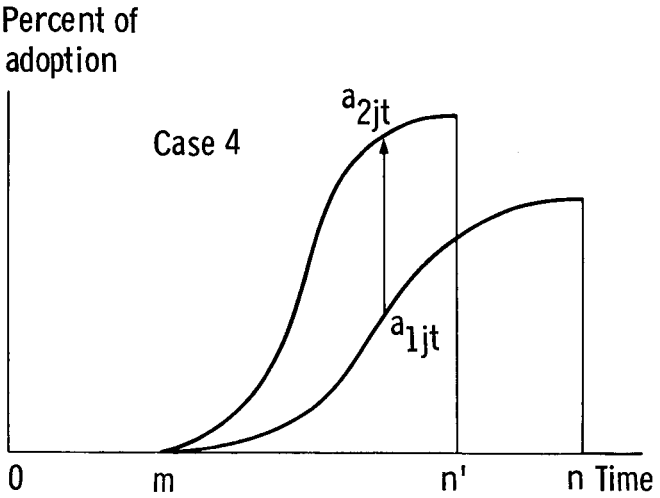


Figure 6. A Change in the Adoption Lag and the Maximum Percentage of Adoption Due to Increased Extension Expenditures.



Summary

This paper describes proposed methodology and procedures to estimate the ex ante, separate internal rates of return to research and extension. The methodology is based on the observations that increased research expenditures will lead to creation of new technology or shorten the leadtime for an emerging technology and increased extension expenditures will either increase the percentage of adoption of a new technology or shorten the length of adoption lag, or both. If appropriate information is available, it is possible to estimate the separate effects of research and extension.

Generally, research and development leadtimes and technology adoption lags are lengthy and good ex post information on the separate marginal effects of increases in research expenditures on leadtime length and increases in extension expenditures on adoption lags is not available. This study proposes to use an ex ante approach to collect this information.

One mailed Delphi survey and two technology workshops are planned to obtain information about the effects of increased research and extension expenditures on the production and adoption of new technologies. The mailed Delphi survey identifies emerging technologies which are expected to have unprecedented impacts on agricultural production in the next 50 years. In the emerging technology workshop, a panel of scientists will estimate changes in the date of commercial introduction of a new technology in

agriculture due to increases in research expenditures. From the technology adoption workshop, changes in the adoption profile due to increases in extension expenditures will be estimated. From the above information, the separate rates of return to research and extension can be computed.

Footnotes

1/An ex ante analysis is based on subjective information rather than historical observations. This paper describes the methodology and procedures for using an ex ante analysis to estimate the rates of future return to research and extension.

2/See George Norton and Jeff Davis (1979) and Robert J.R. Sim and Richard L. Gardner (1978) for reviews of literature on research and extension evaluation in agriculture.

3/Information on resource use and environment will be used in the evaluation of the impacts of emerging technologies in later studies.

References

{1} Bregman, Howard, Ruth Katz, and John Salasin. An Approach to Selecting Panels of Experts. MITRE Technical Report Number 7482, 1977.

{2} Linston, Harold A., and Murray Turoff. The Delphi Method. Reading, Massachusetts. Addison-Wesley, 1975.

{3} Mansfield, Edwin. "Techological Change: Measurement, Determinants, Diffusion." Report to the Presdient by the National Commission on Technology, Automation, and Economic Progress. Washington, D.C., 1966.

{4} Norton, George and Jeff Davis. "Review of Methods Used to Evaluate Returns to Agricultural Research." Staff Paper, P79-16, Department of Agricultural and Applied Economics, University of Minnesota, May, 1979.

{5} Rosenberg, Nathan. Perspectives on Technology. Cambridge, England: Cambridge University Press, 1976.

{6} Sim, Robert J.R. and Richard Gardner. "A Review of Research and Extension in Agriculture." A.E. Research Series No. 214. Dept. of Agricultural Economics, University of Idaho, May 1978.

{7} Sprague, G.F. "Hybrid Corn." After a Hundred Years: Yearbook of Agriculture, Washington, D.C.: GPO 1962. pp. 106-107.