OCCASIONAL PAPERS

Number 25

RESEARCH AND EXTENSION IN AGRICULTURAL DEVELOPMENT

Robert E. Evenson

INTERNATIONAL CENTER FOR ECONOMIC GROWTH

Research and Extension in Agricultural Development

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An International Center for Economic Growth Publication

ICS Press
San Francisco, California

Inquiries, book orders, and catalog requests should be addressed to ICS Press, 243 Kearny Street, San Francisco, California 94108, USA. Telephone: (415) 981-5353; Fax: (415) 986-4878; book orders within the continental United States: **(800) 326-0263.**

Distributed to the trade by National Book Network, Lanham, Maryland.

Evenson, Robert E. (Robert Eugene), 1934-
Research and extension in agricultural development / Robert E. Evenson.
p. cm. — (Occasional paper / International Center for Economic Growth ; no. 25)
"An International Center for Economic Growth publication."
Includes bibliographical references.
ISBN 1-55815-183-4
1. Agriculture—Research—Economic aspects. 2. Agricultural extension work—Economic aspects. 3. Agricultural productivity. I. Title. II. Series: Occasional papers (International Center for Economic Growth) ; no. 25.
S540.E25E84 1991
338.1'6—dc20 91-34529
CIP

PREFACE

The International Center for Economic Growth is pleased to publish Robert E. Evenson's *Research and Extension in Agricultural Development* as the twenty-fifth in our series of Occasional Papers, which feature reflections on broad policy issues by noted scholars and policy makers.

Dr. Evenson evaluates and summarizes studies measuring the contributions of investment in technology and human capital to the growth of agricultural production in developed and developing countries. He carefully analyzes each study's success in revealing the real progress that can be attributed to research and extension programs and shows that some successes may go undetected—or understated—by the research methods currently used. He elucidates the mechanisms—both official and unofficial—through which knowledge and new technology flow, knowledge that comes from research but reaches beyond official extension efforts.

It is imperative that policy makers understand the contribution of research and extension programs in its entirety. These programs are low-cost sources of growth whose use is already on the rise in response to research that accurately reports their effectiveness. We believe that decision makers involved in the creation and expansion of research and extension efforts will benefit from Dr. Evenson's analysis.

Dr. Evenson has spearheaded research in this area around the world over the past twenty years, and his own technological and policy insights will be very useful to economists and policy makers.

Nicolás Ardito-Barletta
General Director
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September 1991

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Robert E. Evenson is a professor of economics at Yale University. He has been an associate professor at both Yale and the University of Minnesota, where he received his B.A. and his M.Sc. He received his Ph.D. from the University of Chicago. He has also served as an associate on the Agricultural Development Council in the Philippines. Dr. Evenson is coauthor of *Science for Agriculture* with Walter Huffman, *Research and Productivity in Asian Agriculture* with Carl E. Pray and associates, and numerous articles.

ROBERT E. EVENSON

Research and Extension in Agricultural Development

Agricultural research and extension programs, complemented by the schooling of farmers and farm workers, are now recognized as important determinants of farmer efficiency and productivity in both developed and developing countries. A considerable body of economic studies focusing on the economic contribution of agricultural research programs, primarily in the public sector, has also been developed since the pioneering studies of Schultz (1954) and Griliches (1958). Only a few studies have been made of the contribution of private sector research and development (R&D) to agricultural productivity. A number of economic studies of agricultural extension have also been made, and several of these have examined the contributions to productivity of the interactions between research and extension and between extension and farmers' schooling. A number of studies have also documented the economic value of farmers' schooling in developing countries (Jamison and Lau 1982). These studies generally conclude that the value of farmers' schooling is higher in economies where a significant flow of new technology suited to the locations in question is being made available to farmers. This paper reviews the literature measuring the contribution of research and extension.

The first section of this paper develops the economic logic underlying the public and private incentives to invest in research and extension and the mechanisms by which such investments create economic value. This logic is then related to methodologies used in research evaluation studies. The second section provides a comprehensive review of studies of extension and farmers' information sources, knowledge, technology, and farm practice adoption, and their impact on farm production and productivity. The third section provides a comparable review of studies of agricultural research programs. These reviews encompass studies using statistical as well as nonstatistical methods. National public sector and private sector programs and international agricultural research centers have been studied. Several studies have also examined the interaction between research and extension programs and farmer schooling.

The final section of this paper attempts to draw out the major policy lessons that these studies provide. Comparative estimated returns on investment are utilized as a basis for discussing expected future payoffs to investment and the complementarities between investments in research and extension and other investments. The relative costs and benefits of research, extension, and schooling in developing countries are considered, as are incentives for private sector investment.

The Economic Logic of Agricultural Technology, Production, and Diffusion

Agricultural research programs supported by national and state governments were built in response to the recognition that "intellectual property rights" in the form of patents were inadequate as incentives to agricultural invention. Improvements in machines and chemicals, stimulated by the patent system in the United States and elsewhere in the late nineteenth century, were impressive and important. Improvements in plants and animals and in most farm practices, however, were not covered by patent laws. The successful experiences of the agricultural experiment stations in Rothamstead, England, and in Saxony in the mid-1800s provided an alternative model for agricultural invention. From 1875 to 1900 numerous agricultural experiment stations were established in many countries. Many of today's developing countries had established experiment stations by the early part of this century; most were directed to the colonial export crops of tea, coffee, and sugar.

Agricultural extension programs in the public sector emerged later in response to farmer demand for information and a perception by program scientists and administrators that the valuable technologies being produced by research programs were not being adopted by farmers. Information and advisory services were required to facilitate this adoption.

Figure 1 depicts the relationship between types of human capital skills in the production and diffusion of agricultural technology and the products with which they are associated. The products (and their associated skill types) are presented in a hierarchical fashion because each higher order product is, or can be, a productive input into the production process below it. The central product of agricultural research systems is the agricultural invention (item 5 in Figure 1) as typified by a new crop variety.

The term "invention" is used here in a broad sense, covering mechanical, biochemical, chemical, electrical, and even managerial inventions of new technology. The development of inventions induces subinventions, which are derivative modifications of inventions. On-farm and farming system researchers engage in subinvention as they seek to improve farming systems.[1] Much agronomic research is of this type. Some extension workers and farmers also engage in subinvention. Communication of technical and price information, the specialty of extension systems, enhances technical choice and farm management decisions by farmers.

Product levels that precede the actual invention of new technology are important because they determine invention potential through the production of pre-invention "germplasm." There is a natural sense in which genetic resources serve in a "parental" role in facilitating the development of biological inventions, such as improved plants or animals. In other words, we can broaden the definition of parental material to include genetic, mechanical, chemical, and intellectual "germplasm."[2] Many systems institutionalize this critical pre-invention stage within experiment stations. As depicted in Figure 1, general scientists produce some agricultural pre-invention germplasm, but in a less focused and directed way than do the agricultural scientists working in experiment stations.

FIGURE 1 Human Capital Dimensions of Technology Production and Diffusion

Skills level	Human capital product	Farmers	Extension workers	On-farm and farming system researchers	Specialists: Applied agricultural scientists	Specialists: Basic agricultural scientists	Specialists: General scientists
1	General science					x	xxx
2	Pre-invention germplasm				x	xxx	x
3	Technology invention			x	xxx	x	
4	Subinvention	x	x	xxx	xx		
5	Information communication	xx	xxx	xx	x		
6	Technology choice decision	xxx	x	x			
7	Farm management decision	xxx	x				

NOTE: x indicates relative importance.

Spatial or spill-in dimensions. Inventions vary greatly in their "location specificity," or their level of adaptation to the specific needs and conditions of the place of invention. Each step away from general science on the hierarchy in Figure 1 represents increased location specificity of human capital products. This reduces the likelihood of "spill-in"—the successful transfer of technology to an area outside its place of invention. Management and technology choices must be made by each farm manager, and there is virtually no spill-in of these products, although general information about technology, prices, weather, and the like does spill in across divergent environments, as does the use of agricultural chemicals. Crop varieties, particularly corn, have a high degree of location specificity because of the reaction of certain genotypes to the environment. Many mechanical inventions are also specific to the location for which they were developed. Conversely, the likelihood of spill-in increases at the level of pre-invention germplasm.[3]

Subinventions, because they are derivatives of inventions, will have a higher degree of location specificity than the inventions from which they are derived. Farming systems management recommendations, for example, may be seen as a modification or subinvention with high location specificity. Pre-invention germplasm, on the other hand, will typically have quite low location specificity, and general science may have very low location specificity.

Spill-in and system design. Technology system design for agriculture must respect the inherent location specificity of the products in question. A given location must have specialists if the product does not spill in (for example, items 1 and 2 in Figure 1). Specialists are not needed provided that the product will spill from a reasonable "spill way"—that is, the channel through which technology flows—to the location with low locational friction, and the receiving location has the skills to interpret and screen information relevant to the product.

In many locations in the developing world in the 1950s the extent of real spill ways for most agricultural technology was seriously overestimated. Many goverments concluded that it was necessary to invest only in information (extension) systems and some subinvention systems, and that they could forgo investing in applied agricultural research because they were located in good spill ways. Most locations found that the spill ways differed a great deal and contained few good research programs. Both national and international research programs located in the tropics and subtropics had high payoffs because they produced technology for their specific locations. Today, a complex system of international, national, regional, and branch research stations and extension systems has emerged in response to experience with limited spill-in of technology.

Timing relationships. Each human capital product in Figure 1 has a life cycle (that is related to the spatial dimension) in which it is produced and enters into economic use. After use, it may be superseded by a substitute or a follow-on product that builds on the initial product. If it is superseded by a product that is additive, its lifetime will be permanent even though the original product is rendered obsolete. If it is superseded by an entirely different product, its effect on productivity will decline and it will then depreciate.[4]

Farm management decisions typically have a short life because next year's decisions may depend on new information. Most extension information also has a short life because of new, nonadditive information. New technology typically has a longer life because even when inventions are superseded, the new inventions are built upon the old inventions (through the parentage mechanism). Crop and animal technology may decrease in effectiveness, however, with exposure to the environment such as in cases where pests and pathogens become resistant to technology after exposure.

Methods used in extension studies. The potential scope for a pay-off on investment in public sector extension will depend on the effective gap between current farm productivity and the potential productivity given the existing "best technology" and "best management" for farms in a particular region. Effective agricultural extension can close both the technology and the management gaps. As these gaps are reduced, the marginal returns on extension are diminished. If further research generates new technology, or changes in market conditions require adjustments in farmers' operations, the market and technology changes provide a role for continuing extension.

The definition of the roles and responsibilities of agricultural extension agents has changed over time. After World War II most developing countries established formal agricultural extension programs. In most of these programs agricultural extension agents not only had educational duties, but frequently supplied inputs and credit as well. Many extension systems were built with insufficient attention to the skill level of field agents. In some systems the bulk of the field staff had little scientific or technical training and virtually no farm experience. Budgetary instability often meant that field staff received little logistic and transportation support. By the mid-1970s many agricultural extension observers recognized that the program was hampered by these skill and support problems.

During the late 1970s the World Bank encouraged a restructuring of traditional agricultural extension practices. In an effort to make these systems more effective, it established the training and visit (T&V) system.

Under the T&V system agents meet with selected contact farmers or farmer groups on regularly scheduled visits. The agents also meet with their colleagues and supervisors at the regional level to discuss problems and their solutions. Agents have two primary duties: transferring agricultural information and reporting farmers' problems. Management education is a secondary objective. The T&V system also provides for better communication between research and extension.[5]

Extension generally follows the sequence described below. First, extension information must be communicated. Second, a process of knowledge formation or observations of the experiments made by other farmers usually leads to farmer experimentation. If an innovation proves productive and relevant to the needs of a farmer, gradual adoption of the new practice may take place. With the adoption of improved technology, complementary changes in other input levels may take place. Output and profits will be expected to increase.

Ideally, extension effects should be estimated in a framework resembling a simulated experiment. It is difficult, however, to find situations in which an actual experiment has been undertaken. Consequently, the approach commonly used is a statistical analysis relying on data measuring extension activities at the farm level. Alternatively, the statistical analysis can be undertaken where observations refer to aggregate extension services supplied to a given region in a specific time period. There are potential biases in the estimation of extension's effect on production, depending on the level of analysis.

An experimental design approach would require data collected before and after an extension investment is initiated, both for the investment area and for an identical area where no investment is made (the "control" area).[6] In reality, few projects are designed so that a control area is available, and adequate pre-extension data sets are usually not available. Only one study of extension effects using an experimental approach has been undertaken.[7] The lack of reliable data usually forces various compromises and approximations.

Methods used in research evaluation studies. The categories below classify research evaluation studies.

- Imputation-accounting studies
- Metaproduction function studies
- TFP decomposition studies
- Metaprofits function studies

These four classes of studies are in roughly chronological order. The prefix "meta" is used here to refer to specifications that do not treat technology as fixed and given. Instead they include variables that seek to act as proxies for flows of human capital products. These variables are usually based on measures of investment in the activity (for example, on research or extension) rather than on direct measures of the human capital product in question. In addition, the hierarchical, spatial (or spill-in), and timing dimensions discussed previously must be addressed.

In general, the imputation-accounting studies have relied directly on proxies for human capital products and hence have avoided many of the following specification issues. The total factor productivity (TFP) decomposition studies, however, are indirectly a form of metafunction study, and thus the issue of specifying human capital variables arises in the same form in these studies.

The basic procedure used in imputation-accounting studies concentrating on evaluating the contribution of agricultural technology follows.

- Identifying the invented technology. In most cases the technology is a *set* of inventions rather than a single invention. In a study of hybrid corn, for example, many hybrid varieties were considered.

- Documenting all costs associated with developing, producing, and diffusing the inventions. With hybrid corn this included all public and private costs incurred as long as twenty-five or thirty years before the realization of benefits. Extension costs should be included in this evaluation.

- Estimating the cost advantage of early adoption. Some studies have utilized experiment station trials to make controlled comparisons of yield and cost before and after adoption. Most studies have attempted to obtain farm level comparisons, but these comparisons are generally not representative of farmer fields. In the hybrid corn study both experiment station and farm data were used.

- Estimating the adoption pattern and the advantage of early adoption. In general, new inventions will be adopted first on economic units where the cost advantage is greatest. As adoption spreads, the advantage typically declines (unless, as with hybrid corn, the technology as defined is undergoing continuous change). Extension and schooling studies seek to associate the speed of adoption and the adoption-advantage pattern to investment in extension.

- Converting the latter two estimations to a benefits stream.

Imputation-accounting studies, then, have generally sought to estimate the shifts in supply curves from cost data. They have also estimated (or all too often simply assumed) the units over which these skills apply. Adoption rates are generally used to determine these units.

The metaproduction function is a statistical approach and entails the estimation of a production function including research and extension (and schooling) variables based on investment data. The procedure is to construct a stock variable using spatial (or spill-in) weights[8] and time weights.[9] Some studies also consider the aggregations of the research and sometimes the extension variables over commodity research subaggregates. This aggregation is related to the spillover of research contributions from one commodity to another. Most studies have used commodity production weights in forming aggregates. This generally implies that no commodity spillover takes place. Other studies have used multiple deflators to allow for more flexible effects (see Huffman and Evenson 1991).

TFP decomposition studies are closely related to metaproduction function studies because TFP measures can be derived from a production function framework. Most recent TFP measures, however, are derived from accounting relationships and use a form of superlative index number methodology (for example, the Tornqvist approximation to the Divisia index).

In the two stages of the TFP decomposition procedure one first computes TFP measures allowing location and time period weights to vary and then pools these measures in a TFP decomposition statistical specification using research, extension, and school variables.[10]

The most recent development in the evaluation of the effects of human capital is the use of the metaprofits function system where human capital variables (research, extension, and schooling) are incorporated directly into systems of output supply and factor demand equations. These studies are an advance over the second generation studies: they allow for multiple outputs and they allow the measurement of separate research effects on each output supplied and on each variable factor demanded.

The methodology of the metaprofits function system is based on the maximized-profits function where farm profits are expressed as a function of all prices of variable outputs and factors and on fixed factors and metatechnology variables. The first partial derivative of this function with respect to an output (or input) price is the supply (or demand) function for that output (or input). In this way a system including an equation for each ouput supplied and each factor demanded is estimated jointly. Each equation includes the prices and metatechnology variables.

Cost considerations. An important factor in the calculation of returns on investment in research, extension, and schooling is the cost of the resources. It is not widely appreciated that research staff time and particularly extension staff time is low priced in developing countries—that is, low priced relative to other growth-producing inventions such as irrigation equipment or fertilizer.

Table 1 summarizes comparative data concerning spending on extension and research. It also shows expenditures per scientist compared with expenditures per extension worker for the given years. The table shows that low income countries were spending approximately twice as much on extension as on research in 1959. By 1980 most developing countries were spending as much on extension as on research. The data on expenditures per scientist and extension worker also indicate

TABLE 1 Public Sector Research and Extension Expenditures, 1959, 1970, and 1980

Country group	Agricultural research expenditures (% of value of agricultural product)			Agricultural extension expenditures (% of value of agricultural product)		
	1959	1970	1980	1959	1970	1980
Low-income developing	.15	.27	.50	.30	.43	.44
Middle-income developing	.29	.57	.81	.60	1.01	.92
Semi-industrialized	.29	.54	.73	.29	.51	.59
Industrialized	.68	1.37	1.50	.38	.57	.62
Planned	.33	.73	.66	—	—	—
Planned (excluding China)	.45	.75	.73	.29	.33	.36
	Research expenditures per scientist year (thousands of 1980 U.S. $)			Extension expenditures per extension worker year (thousands of 1980 U.S. $)		
	1959	1970	1980	1959	1970	1980
Low-income developing	34	40	47	2.0	2.0	2.0
Middle-income developing	42	44	47	7.0	7.0	6.0
Semi-industrialized	41	45	46	10	10	11
Industrialized	55	80	93	16	25	29
Planned	33	32	31	—	—	—
Planned (excluding China)	31	25	30	13	13	14

NOTE: Dash = not available.
SOURCE: Judd, Boyce, and Evenson 1986.

that extension staff were, and remain, low cost relative to research staff in the lower income countries. Developing countries appear to have seen higher investment opportunities in research than in extension over this period.[11] Several studies of public sector investment decisions regarding research and extension have also been made (for example, see Evenson 1987). They do show investment responsiveness to economic opportunities as reflected in studies of returns on investment.

Studies of Returns on Extension

The studies reviewed in this section sought to measure the impact of public agricultural extension programs on farmer knowledge, technology, and farm practices; adoption or use of technology and practices; farmer productivity and efficiency; and farm output supply and factor demand. The first three categories of studies will be summarized in this section. The fourth will be discussed in the section on the contributions of agricultural research because these studies estimated both research and extension effects.

Studies that measure extension impact at the individual farm level may be affected by two basic estimation problems. The first is the problem of farmer self-selection. A researcher identifying the extension variable as some form of extension contact typically treats the extension variable as exogenous (that is, not determined by the farmer). It is likely, however, that the more productive farmers will desire to acquire information about changing farm conditions or new technologies. Such farmers may be inclined to attend more demonstration days, read more literature, and seek out extension contact. Extension agents themselves may also seek out contacts with the better farmers. In such a case the estimates of extension impact on farmers' performance are likely to be biased upward, because some of the improved performance attributed to extension would in fact be the result of the superiority of the group that interacts with extension (or of the extension agents themselves). The problem of self-selection can, in principle, be handled econometrically, but this has rarely been done.

The second source of potential bias is indirect or secondary information flows, in which farmers with direct extension contact pass