THE MART/AZR PROJECT

HIGH ELEVATION RESEARCH IN PAKISTAN

Pakistan Agricultural Research Council

ARID ZONE RESEARCH INSTITUTE

Brewery Road, Quetta, Pakistan.

No. 2

THE PRODUCTION FUNCTION AND PRODUCTIVITY INDEX APPROACHES TO ESTIMATING RETURNS OF AGRICULTURAL RESEARCH

by

J.G. NAGY

1987

MART/AZR PROJECT RESEARCH REPORTS

This research report series is issued by the Management of Agricultural Research and Technology Project/Arid Zone Research Component (MART/AZR). This project is sponsored financially by the Mission to Pakistan of the United States Agency for International Development (USAID).

The project contract is implemented by the International Center for Agricultural Research in the Dry Areas (ICARDA) and Colorado State University (CSU) at the Pakistan Agricultural Research Council's Arid Zone Research Institute (AZRI).

This Institute has responsibility for undertaking dryland agricultural research in all provinces in Pakistan through its headquarters in Quetta, Baluchistan and its sub-stations at D.I. Khan (NWFP), Umerkot (Sind) and Bahawalpur (Punjab)

The principal objective of the MART/AZR Project is the institutional support and development of AZRI in the period 1985-1989. This series of research reports outlines the joint research findings of the MART/AZR Project and AZRI. It will encompass a broad range of subjects within the sphere of dryland agricultural research and is aimed at researchers, extension workers and agricultural policy-makers concerned with the development of the resource-poor, arid areas of West Asia and the Middle East.

Libraries, individuals and institutions may obtain single copies of this research report series free of charge and may request that their names be placed on a mailing list for periodic notifications of published papers by writing to the MART/AZR Project Office, P.O. Box 362, Quetta, Pakistan.

The Production Function and Productivity Index Approaches to Estimating Returns to Agricultural Research.[1]

Joseph G. Nagy[2]

The aim of this paper is to briefly introduce the production function and productivity index approaches used in the estimation of the returns to agricultural research. The paper, for the most part, summarizes Davis (1981) and Lu et. al.,(1979). A list of production function type studies for various commodities and countries with their associated rates of return are found in Ruttan (1982, pp. 242-246). For further information, good literature reviews on the topic are presented in Davis (1979) and Norton and Davis (1981).

I. An Overview.

The production function approach is based on the same idea as other approaches to the estimation of rates of return. That is, there are costs to doing research and these costs have benefits. Once the costs and benefits are found, a calculation can then be undertaken to obtain the rate of return.

The method is similar to estimating a production function with the level of agricultural output being a function of the traditional inputs of land, labor and capital. The difference is that non-conventional inputs such as research and extension are included as separate arguments. Norton and Davis (1981) portray the basic model as follows:

$$(1) \qquad Q = A \prod_{i=1}^{m} X_i^{b_i} \prod_{j=o}^{n} R_{t-j}^{a_{t-j}} e^{u}, \quad \text{Where;}$$

Q = value of agricultural output;
A = shift factor;
X_i = i^{th} conventional production input;
R_{t-j} = expenditures on research (and Extension) in the $t-j^{th}$ year;
b_i = the production coefficient of the i^{th} conventional input;
a_{t-j} = the partial production coefficient of research (and extension) in the $t-j^{th}$ year; and
u = random error term.

----

[1] Presented at the Economic Research Policy Workshop, Agriculture University of Faisalabad, Faisalabad, Pakistan, March 8-19, 1987.

[2] Economist, International Center for Agricultural Research in the Dry Areas (ICARDA) on the MART/AZR project, Arid Zone Research Institute, Quetta, Pakistan.

The productivity index approach, as set out by Lu et. al. (1979), is as follows; the level of agricultural productivity is a function of the current weather conditions, the current education level of farmers, and the impact of research (and extension). The main difference to that of the production function approach is that the conventional inputs are brought over to the dependent side of the equation by the formulation of a productivity index. The model can be specified as follows:

$$(2)\quad PI = A W^{c} E^{d} \prod_{j=o}^{n} R_{t-j}^{a_{t-j}} e^{u}, \quad \text{Where;}$$

PI = a productivity index of agricultural output;
W = weather index;
E = measure of the education level of farmers;
c&d = productivity coefficients for the associated inputs.

Cross-section or pooled cross-section/time series data are most often used in the estimation of equation (1). Estimation problems such as multicollinearity among the input variables deter the use of time series data. Most of the studies have used the Cobb-Douglas specification although other specifications such as a translog specification can also be used - data permitting.

Most of the productivity index studies have used a Cobb-Douglas specification with time series data. The use of a productivity index circumvents the multicollinearity problems that exist among the conventional input variables when trying to use time series data in a regular production function.

II. The Rate of Return Calculation

Once equation (1) or (2) is estimated, a two step procedure is taken to calculate the rate of return. The first step is to calculate the total or set of value marginal products of the research variable R (VMPR). This is done by multiplying the research production coefficients from equation (1) or (2) by the average product of research. For the production function approach using cross-section data which estimates a total production coefficient for R, the VMPR is calculated as:

(3) $VMPR = a \times \bar{Q}/\bar{R}$, Where;

$\underline{a}$ = total production coefficient of research (R);
$\bar{Q}$ = the average valve of output over the time period of interest, and
$\bar{R}$ = the average research expenditure over the same period.

To calculate the VMPR for the productivity index approach is slightly more complicated because the dependent variable is a productivity index which is not in value terms as Q is in equation (3). The VMPR calculations for a productivity index approach that is estimated using time series data and using a technique such as an Almon polynomial lag to estimate the partial production coefficients for research over time as given by Lu et. al., (1979) is as follows;

(4) $VMP_{t-i} = a_i PI/R \times AY_t/AP_t$, Where;

$VMPR_{t-i}$ = Value of the Marginal product of research in period t-i;
a_i = the partial production coefficient of research;
PI = the average of the productivity index for the period of concern;
AY = the change in the value of output net of the change in the value of inputs;
API = the change in the productivity index between years (thus AY/API is the value (price) of one unit of productivity index - see Lu et. al., 1979 for the theoretical basis).

The second step is to calculate the discount rate or the marginal internal rate of return (MIRR) which equates the discounted flow of the benefits with the discounted research cost.

The calculation of MIRR depends upon how one conceptualizes the lag between research expenditures and benefits from the expenditures and the type and the form of the research variable used and how the production coefficient of research is estimated. Davis (1981) summarizes several studies that have conceptualized the research lag and estimated the production coefficients for research differently.

1) assume all benefits occur in one year (Griliches, 1964 as cited by Davis, 1981). This approach is very simplistic and does not take into consideration a time lag between research expenditures and the benefits from the expenditures.

2) assume a lag where the VMPR is attained n years after the research expenditure but that the same returns continue into perpetuity This is the Peterson Poultry Study (1967) where a Cobb-Douglas production function was estimated with cross-section data for the year 1959 and the research variable was the average of the 1954 & 1956 research expenditures.

3) assume that the lag between research expenditures and benefits is represented by an inverted V with a mean lag of 6 to 7 years (Evenson, 1967). Thus, the VMPR is weighted and the formula for the MIRR becomes;

$$(5) \quad VMPR \left[\sum_{i=1}^{n} W_i/(1 + MIRR)^i \right] - 1 = 0, \text{ Where;}$$

W_i = the weight for period i, and
n = the total number of years over which past research has an impact on output.

4) unlike the above three methods which estimated a total production coefficient for research, estimate the partial production coefficients using a procedure such as a Almon polynomial lag. Thus the weights are estimated unlike the weights in equation (5) above. The statistical criteria of $\bar{R}^2$ or the standard error of estimate can then be used to determine which lag length is the most appropriate (Lu et. al., 1979). This procedure is used with time series data and in particular with the productivity index approach. The MIRR formula is as follows:

$$(6) \quad \left[\sum_{i=o}^{n} VMPR_i/(1+MIRR)^i \right] -1 = 0, \text{ Where,}$$

$VMPR_i$ = the value of the marginal product of research associated with each partial production coefficient a_i.

III. Specific Topics

A. Forms of the Research Variable

The use of the annual public expenditure on research (and Extension) has been the most popular method used to specify the research variable R and is explicitly assumed in the above discussions. Discussions have taken place that indicate that a better measure for the research variable would be a measure of the output of the research sector - since research output is the input into agricultural production - rather than expenditures which are an input into the research sector (Araji, 1980). Evenson (1974) has used the number of scientific journals produced by the public research sector as a proxy for the output of the research sector. Another alternative is to use a measure of the introduction of the new technology i.e., the percentage of a crop that is known to come from new varieties or from other technologies. The use of expenditure data, however, remains the most popular because of its availability.

B. Spillover Effects

Research in one country or part of a country (i.e., from different States in the USA) can have an effect on the agricultural productivity in another country or State. Thus, these spillover effects should be taken into account so as not to bias the results. Several studies have included a spillover variable as an argument in the production function. Norton (1981), when estimating the returns to cash grains, dairy, poultry, and other livestock for the USA included a spillover variable (S) which is specified as the expenditure on research in other states affecting each state. Sundquist et. al.(1981) used a similar spillover method in arriving at the returns from corn, wheat and soybean research for the USA. Although crude, this method can pick up some of the spillover effects from research.

C. Research From Non-Public Research Agencies.

In many cases, research is undertaken by private agencies and individuals as well as by public institutions. Thus, the effect on productivity from private research must be accounted for when estimating the rates of returns to research. A possible approach is to include the expenditures for both private and public research as separate arguments. Peterson (1967), reduced the marginal product of research to one-third of its estimated value before calculating the rate of return based on the fact that public expenditures were one-third of total (public plus private) research expenditures.

References

Araji, A. A., 1980. Research and extension productivity in agriculture. University of Idaho, Moscow, Idaho.

Davis, J.S., 1981. A comparison of procedures for estimating returns to research using production functions. Australian Journal of Agriculture Economics.

Davis, J.S., 1979. Stability of the research production function coefficient for U.S. agriculture. Unpublished Ph.D. Thesis, University of Minnesota, St. Paul, Minnesota.

Evenson, R.E. 1967. The contribution of agricultural research to production. Journal of Farm Economics. 49(5).

Evenson, R.E. 1974. The green revolution in recent development experience. American Journal of Economics, 56.

Lu, Y., Cline, P. and Quance L. 1979. Prospects for productivity growth in U.S. Agriculture. U.S. Department of Agriculture, Economics, Washington, D.C.: Statistics and Cooperatives Service, Report No. 435.

Norton, G. 1981. The productivity and allocation of research: U.S. agricultural experimental stations revisited. In: Evaluation of agricultural research. Minnesota Agricultural Experiment Station, Misc. Publications 8-1981, University of Minnesota, Minneapolis.

Norton, G.,and Davis, J. 1981. Review of methods used to evaluate returns to agricultural research. In: Evaluation of agricultural research. Minnesota Agricultural Experiment Station, Misc. Publications 8-1981, University of Minnesota, Minneapolis.

Peterson, W.L. 1971. The returns to investments in agricultural research in the United States. In: Resource allocation in agricultural research. W.L. Fishel ed. University of Minnesota Press, Minneapolis, Mn.

Peterson, W.L. 1967. Returns to poultry research in the United States. Journal of Farm Economics, 49.

Ruttan, V.W. 1982. Agricultural research policy. University of Minnesota Press, Minneapolis, Mn.

Sundquist, W.B., Cheng, C.G. and Norton, G. 1981. Measuring returns to research expenditures for corn, wheat, and soybeans. In: Evaluation of agricultural research. Minnesota Agricultural Experiment Station, Misc. Publications 8-1981, University of Minnesota, Minneapolis, Mn.