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A COMPARISON OF ALTERNATIVE PROCEDURES FOR CALCULATING THE RATE OF RETURN TO AGRICULTURAL RESEARCH USING THE PRODUCTION FUNCTION APPROACH

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A COMPARISON OF ALTERNATIVE PROCEDURES FOR CALCULATING THE RATE OF RETURN TO AGRICULTURAL RESEARCH USING THE PRODUCTION FUNCTION APPROACH

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ABSTRACT

The aim of this paper is to test whether the marginal internal rate of return (MIRR) to research and extension estimates are sensitive to the estimation procedure used to find them. To achieve this, a summary of the previously used estimation procedures is made. Following this a cross section aggregate production function estimate is developed for the U.S. in 1964. The parameter estimates from this model are used to calculate the MIRR's using the different estimation procedures. The results indicate a range in these estimates from 23.9 to 49.7 percent. The implication, then, is that careful consideration should be given to the choice of estimation procedure, both when undertaking a study of this sort and also when comparing the results of different studies.

1. Introduction

During the last 20 years there has been a strong growth in the number of studies that have estimated the rate of return to agricultural research and extension.[1/] The main emphasis of this work has been on ex-post evaluation and the majority of studies have used either the index number or production function approaches.[2/] For use in decision making, a marginal rate of return is most appropriate. Since the production function approach most readily gives a marginal rate, where data availability permits, this approach has been preferred. For this approach, however, there has been little discussion (in the literature) of the estimation procedure used to find the rate of return once the production coefficients have been estimated. The aim of this paper is to summarize the various procedures that have been used and to determine whether the rate of return estimates are sensitive to the procedure used.

The next section reviews the estimation procedures used in previous studies. The third section briefly discusses the estimation of a cross-section production function for the U.S. in 1964 and uses this estimate to calculate the rate of return using each of the procedures discussed.

2. A Review of Previous Estimation Procedures

The basic model used by the production function approach is:

$$Q = A \prod_{i=1}^{m} X_i^{\beta_i} \prod_{\ell=0}^{n} R_{t-\ell}^{\alpha_{t-\ell}} e^{u} \qquad (1)$$

where:

- Q is the per farm value of agricultural output.
- A is a shift factor.
- X_i are the conventional production inputs.
- $R_{t-\ell}$ are the expenditures on research and extension in years t to $t-n$.
- β_i are the production coefficients on the conventional inputs
- $\alpha_{t-\ell}$ are the partial production coefficients of research and extension.
- u is the random error term.

It has only been in more recent studies, for example Cline (1975), that attempts have been made to estimate the individual $\alpha_{t-\ell}$'s. In most other studies a weighted research and extension variable has been used. Consequently, the production parameter estimate obtained has been of $\alpha = \sum_{\ell=0}^{n} \alpha_{t-\ell}$.

A two-step procedure has then been used to find the marginal internal rate of return (MIRR). That is, first the marginal product of research and extension is found from

$$MPR = \alpha \frac{Q}{R} \quad (2)$$

Since Q represents the value of output, this MPR is in fact the value marginal product of a dollar of research and extension expenditure.

Second, since there is a lag between the expenditure of funds and the realization of the benefits, this MPR is then distributed over some time period. The MIRR of research and extension is then the discount rate which satisfies

$$\text{discounted (MPR)} - 1 = 0 \quad (3)$$

While some variations of equation (2) have been used in different studies, the main sources of differences lie in the specification of equation (3). We will now summarize these different procedures.

The simplest procedure used assumes all benefits occur during the 'n'th year after the expenditure date. In this case, equation (3) becomes

$$\frac{MPR}{(1+\gamma)^n} - 1 = 0$$

or rearranging

$$\gamma = (MPR)^{\frac{1}{n}} - 1 \quad (4)$$

where we now let MIRR $= \gamma$.

Other studies, for example Peterson (1967), have assumed that the marginal product often assumes a lag of 'n' years but that this same return then continues into perpetuity. For this situation the MIRR is found from

$$MPR \left[\sum_{i=n}^{\infty} \frac{1}{(1+\gamma)^{i}} \right] - 1 = 0 \qquad (5)$$

Clearly, if the 'n' in equations (4) and (5) are the same, then the MIRR found from the latter equation will be alot higher than from the former.

Most recent studies have made use of the conclusion of Evenson (1967); that the best representation of this lag is that of an inverted 'V'. However, there have been two slightly different uses made of this conclusion. The best way to illustrate this difference is via figure 1. Evenson (1967) developed a weighting procedure which assumes the marginal product is distributed according to the histogram structure in figure 1(a). On the other hand, Bredahl (1975) suggested that the benefits are spread as the area under the inverted 'V'. This is the shaded area in figure 1(b).

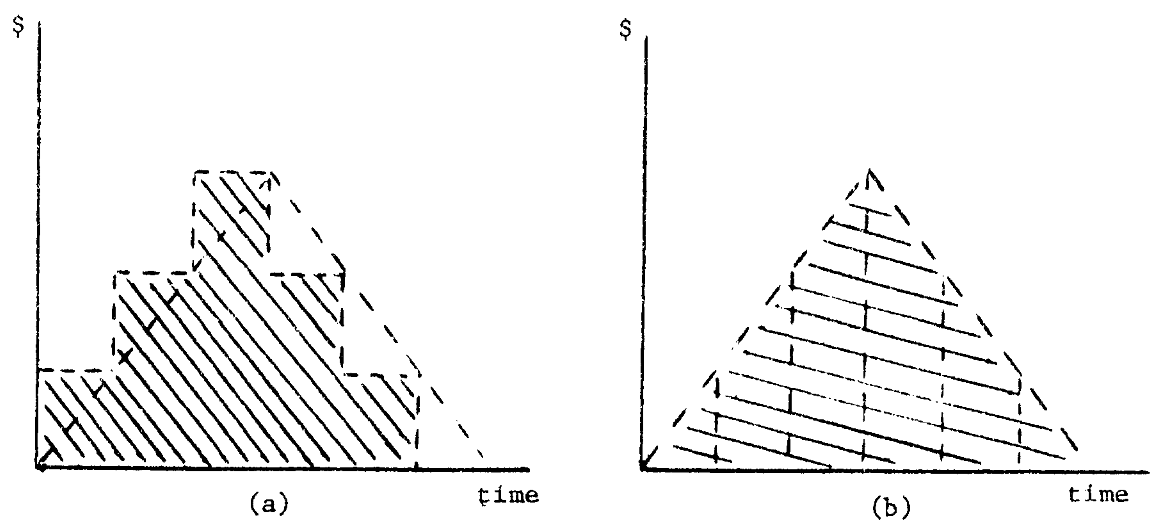

FIGURE 1

Both procedures use the same basic equation to calculate the MIRR, that is,

$$MPR\ [\sum_{i=1}^{n} \frac{w_i}{(1+\gamma)^i}] - 1 = 0 \qquad (6)$$

where: w_i is the weight for period i.

n is the total number of years over which past research has an impact on output. Also $s = \frac{n}{2}$ is called the mean lag.

The main distinction between the two procedures lies in the determination of the weights, w_i. It can be shown that Evenson's procedure uses the weights:

$$w_i = \frac{i}{[s + 2 \sum_{j=1}^{s-1} j]} \qquad (7a)$$

for i = 1 to s

and

$$w_i = \frac{n-i}{[s + 2 \sum_{j=1}^{s-1} j]} \qquad (7b)$$

for i = s + 1 to n.

On the other hand, it can be shown that Bredahl's procedure uses the weights

$$w_i' = \frac{2i-1}{2s^2} \qquad (8a)$$

for i = 1 to s

and

$$w_i = \frac{2n(2i-1)}{2s^2} \qquad (8b)$$

for i = s + 1 to n.

The easiest way to see the difference between the two is to notice that w_n is zero for Evenson's procedure, but not Bredahl's. The result is that more of the benefits accrue in earlier periods for Evenson's procedure.

All of the above procedures have used an estimate of the total production coefficient. More recently, studies have estimated the partial coefficients, therefore, providing scope for using slightly different MIRR estimation procedures. Cline (1975) estimated these partial coefficients and, although he estimated a productivity function, used basically the following estimation procedure. He found the marginal product as

$$MPR = \sum_{i=1}^{n} \alpha_i \frac{\bar{Q}}{\bar{R}}$$

where: $\bar{Q}$ is the average value of output over the time period of interest
$\bar{R}$ is the average research and extension expenditure over the same period

With this estimate he then used an equation similar to equation (6) except that the weights were given by

$$\bar{w}_i = \frac{\alpha_i}{\sum_{i=1}^{n} \alpha_i} \tag{10}$$

The critical aspect of Cline's procedure is determining the length of the period for which the averages for output and research are found.

All of the above procedures, however, lose sight of the use that is to be made of the estimated MIRR. Two possibilities seem to present themselves. The first is that decision makers may wish to know the impact of all previous research and extension on a particular year's output (or set of years' outputs). It is an approximation of this that most past studies have been estimating. The second alternative is that it is desirable to know the impact of one particular year's (or set of years') research and extension on all subsequent years' output. The latter is probably most relevant for decision makers.

The appropriate estimation formulae are, for the first possibility:

$$\sum_{i=1}^{n} \frac{\alpha_i Q_n}{R_i (1+\gamma)^i} - 1 = 0 \tag{11}$$

and, for the second possiblity:

$$\sum_{i=1}^{n} \frac{\alpha_i Q_i}{R_1 (1+\gamma)^i} - 1 = 0 \tag{12}$$

We see the basic difference is that in the first, the level of research and extension expenditure changes for a given output level while in the second, the opposite applies.

In the next section we will use some empirical results to assess the sensitivity of MIRR estimates to the different estimation procedures reviewed above.

3. Some Empirical Results

The same basic production function model as developed by Griliches (1964) was applied to 1964 cross section data. The main difference between Griliches' model and that estimated here was that a second order polynomial lag distribution of research and extension expenditure with a 14-year lag was used. These were constrained such that $\alpha_{t-n-1} = \alpha_{t+1} = 0$ and the Almon estimation procedure used.

The production function coefficient estimates are presented in table 1. From the Almon variable coefficient we can calculate the individual partial production coefficients. That is, from Maddala (1977, p. 358) we see that our partial coefficients are given by

$$\alpha_i = Z_0 + Z_1 i + Z_2 i^2 \tag{13}$$

where: Z_2 is the Almon coefficient estimated in our production function and it can be shown that

$$Z_0 = - Z_2 (n + 1)$$

and

$$Z_1 = - Z_2 n$$

where for our case, n = 14.

For the estimates found here, equation (13) becomes

$$\alpha_i = .001176 + .001092i - .000084i^2$$

and using this we get the partial production coefficients presented in table 2.

The parameter estimates from this estimation were combined with the state geometric mean deflated values for Q and R for periods required by the different estimation procedures discussed in section 2. The MIRR's calculated using these procedures are summarized in table 3. The first thing we notice is a large range in the MIRR estimates from 23.9 to 49.7 percent, although there is a concentration in the 25 to 35 percent range. Two time periods were used for Cline's procedure: the first, 1954 to 1964, is roughly comparable with the impact on 1964 output type estimates; the second estimate, 1964 to 1974, is roughly similar to the value of 1964 research procedures.

Table 1. Cross Section Aggregate
U.S. Production Function Estimate For 1964

Variable Description	Coefficient Estimate	Standard Error of the Estimate
Other Inputs	.382**	.046
Land and Buildings	.018	.018
Labor	.202**	.071
Fertilizer	.107**	.035
Machinery	.481**	.062
Almon Research Variable	-.000084*	.000043
Constant	1.121**	.491
$\bar{R}^2$	.97	

* Significantly different from zero at 95 percent level.
** Significantly different from zero at 99 percent level.

Table 2. Partial Research and Extension Production Coefficients
For 1964 Production Function

Year	Partial Production Coefficient
1964	.001176
1963	.002184
1962	.003024
1961	.003696
1960	.0042
1959	.004536
1958	.004704
1957	.004704
1956	.004536
1955	.0042
1954	.003696
1953	.003024
1952	.002184
1951	.001176
$\sum_{i=1}^{14} \alpha_i$	.047

Table 3. Marginal Internal Rate Of Return Estimates Using Various Estimation Procedures

Estimation Procedure	MIRR Estimate (%)
Equation (4)	23.9
Equation (5) n = 7	46.1
Evenson's-Equation (7a & b)	28.2
Bredahl's-Equation (8a & b)	25.6
Cline's-Equation (9 & 10) 1954-1964	33.2
Increase In 1964 Output-Equation (11)	49.7
Cline's-Equation (9 & 10) 1964-1974	25.0
Returns To 1964 Research & Extension-Equation (12)	30.1

4. Conclusions

The results of the empirical work undertaken in this paper indicate that the MIRR estimate for any set of production function parameter estimates is extremely sensitive to the estimation procedure used. If we are comparing the MIRR's from different studies, we should therefore be careful to check for compatability of estimation procedures. The most appropriate estimation procedure is probably the returns to expenditure in one particular year as found using equation (12).

FOOTNOTES

1/ For a recent summary of the rates of return estimated by these studies see Ruttan (1978; pp. 15-16).

2/ More detailed reviews of these estimation approaches have been given by Peterson (1971) or, more recently, by Norton (1978).

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