PROCEEDINGS

48th Annual Meeting

WESTERN AGRICULTURAL ECONOMICS ASSOCIATION

Reno, Nevada

July 20, 21, 22, 1975

William D. Gorman, Editor

REGIONAL DIFFERENCES IN THE RATE OF RETURN TO AGRICULTURAL RESEARCH AND EXTENSION

Yao-Chi Lu and Philip L. Cline

Oklahoma State University

The uneven public support of research among the farm production regions of the United States has been caused to a great extent by disparity in the funding of state experiment stations. For example, in 1972 regional experiment station expenditures ranged from a high of about 53.5 million dollars in the Corn Belt states to a low of 19.5 million dollars in the Southern Plains states. However, the passage of the Hatch Act in 1887 is not the cause of the unequal growth of the stations. In fact, this Act provides each state equal financial treatment [10]. Inequality of the financial growth of state experiment stations can instead be attributed to two sources. The first source is the passage of the Bankhead Jones Act of 1935 which provides allocations of some federal funds on the basis of farm population [9]. The other source is the rapid growth of nonfederal funds. Since 1910 state appropriations to some stations have exceeded federal funding [10].

In view of wide differences in research funds allocated to the regions, it seems pertinent to ask whether some regions have benefited more than other regions from public investment in research and whether reallocation of these funds among regions would increase the benefits to the nation as a whole. Knowledge regarding social benefits derived from public research expenditures for each region is essential for optimal allocation of research funds among regions.

Research activities produce knowledge which is then transformed into new skills or new materials [10]. Assimilation of these new skills and materials into production processes causes agricultural productivity to increase. Several attempts have been made to measure the social benefits derived from research activity by estimating the rate of return to investment in research activity by estimating the rate of return to investment in research and extension (R&E) for the nation [3, 5, 6]. However, little empirical work has been done on the measurement of rates of return to investment in R&E by farming regions.

The purpose of this study is to measure the rates of returns to public investment in R&E for each of the ten farm production regions defined by the U.S. Department of Agriculture. For reasons to be discussed later, R&E expenditures will be combined as a package in the estimation of the rate of return. Due to lack of data, private R&E expenditures will not be included in this study. Non-production-oriented R&E expenditures were originally included as a separate variable in this study. However, they were dropped because the regression coefficient of that variable was statistically not significant.

CONTRIBUTIONS OF PUBLIC R&E TO PRODUCTIVITY GROWTH

One of the early attempts to measure the rate of return to R&E was made by Griliches [6] using a production function approach. In his study, R&E expenditures and education are included along with other conventional factors of production as inputs to the aggregate production function. To allow for a lag in the effect of the expenditures, Griliches constructs the observations on the R&E variable by averaging the flow of expenditures in the previous year and the level six years previously.

Using a slightly different approach, Evenson [5] fits a linear regression model to time series data of U.S. agriculture for the 1935-1963 period. A productivity index is employed as the dependent variable and the model explains its behavior by current values of public R&E expenditures, weather, and an index of education attainment of farmers. Through a system of predefined weights, the effect of R&E is distributed through time in a manner which exhibits the shape of an inverted V.

A more flexible distributed lag form for the effect of R&E is used in this study. It is hypothesized that agricultural productivity depends upon R&E expenditures, the level of educational attainment of farmers, and weather as follows:

$$(1)\ P_t = \prod_{i=0}^{n} R_{t-i}^{\beta_i}\ E_t^{\beta_{n+1}}\ e^{\beta_{n+2}W_t}$$

where

P_t = the value of the aggregate productivity index for U.S. agriculture in year t,

R_{t-i} = the lagged values of production-oriented research and extension expenditures.

E_t = the value in the current period of an index of educational attainment of farmers,

W_t = the value in the current period of a weather index,

n = the length of lag measured in years.

It is assumed that investment in research will not immediately bear fruit in terms of increases in productivity. There is a lag between the research investment and its impact on productivity. When the research is completed, "extendable information is produced. At this time, the extension of this new knowledge begins and the initial effects on productivity are felt. As adoption of the new technology grows, productivity increases. At some point the contribution of this past R&E will reach a maximum. Then the contribution of the technology to productivity growth will decrease for any one of the following reasons [1,5]. First, it may become obsolete or irrelevant. For example, the technology used in producing mule harnesses is still available; however, it no longer has any significant relevance to agriculture. Second, the value of the technology may depreciate after some point in time due to biological decay. An example of this case is an insect building up resistance to certain insecticides over time. Third, the technology may become obsolete as old inputs are replaced by superior or improved inputs. Finally, changes in relative input prices may make the technology economically obsolete. Thus, the effects of R&E on productivity follows an inverted U shape.

R&E are complementary inputs into this research-extension-output process. But they do not enter the process at the same time. Extension activities lag research, but the length of the lag is not yet known. In this study, we assume that the lag is one year in order to combine R&E expenditures.

ESTIMATION PROCEDURES

To estimate Equation (1), data for each of the ten regions were assembled for the 1939 to 1972 period. Productivity indexes for the 1950 to 1972 period are from the 1973 and 1964 issues of *Changes in Farm Production and Efficiency* [13] and data for the 1939 to 1949 period are from Lambert [8]. R&E expenditures are from Cline [3]. Education indexes are constructed from a series reported by Evenson [5] and weather indexes are constructed from Stallings [11] and Kost [7].

To estimate the parameters, Equation (1) was transformed to the following:

$$(2)\ \ln P_t - \rho \ln P_{t-1} = \sum_{i=0}^{n} \beta_i (\ln R_{t-i} - \rho \ln R_{t-i-1})$$

$$+ \beta_{n+1} (\ln E_t - \rho \ln E_{t-1})$$

$$+ \beta_{n+2} (W_t - \rho W_{t-1}) + e_t$$

where $e_t = u_t - \rho u_{t-1}$. The Almon distributed lag method [2] was used to fit the n β's in the first term of the right-hand side of Equation (2) to a polynomial of suitable degree with varying length of lags and Durbin's [4] two-stage procedure was employed to estimate the ρ parameter.

To overcome high collinearity between the education variable and the R&E variable, an estimate of the education parameter obtained from fitting national data to Equation (2) was incorporated into the model.

The results from fitting Equation (2) to the annual regional data are reported in Table 1. Only the "best" lag length and degree of polynomial (two in all cases) as determined by Theil's [12] minimum standard error of estimate criterion is reported for each region. For each of the regions R&E expenditures affect productivity over time in a manner that is consistent with the hypothesized time form.

REGIONAL RATES OF RETURN TO R&E

Given the specification of the model shown in Equation (2), each individual distributed lag coefficient is a direct estimate of the elasticity of agricultural productivity with respect to R&E expenditures in the appropriate time period.

That is,

$$\beta_i = \frac{\Delta P_t}{\Delta R_{t-i}} \cdot \frac{R_{t-i}}{P_t} ,$$

or

$$\frac{\Delta P_t}{\Delta R_{t-i}} = \frac{P_t}{R_{t-i}} \beta_i .$$

To approximate the marginal product (MP) of R_{t-i}; i.e., the increase in agricultural output brought about by a one dollar increase in R_{t-i}, the above equation is multiplied by the average net increase in the value of output over the period under study due to a one point increase in productivity and the ratio of the average level of productivity to the average level of R&E expenditures over the time period was substituted for P_t/R_{t-i}:

$$MP_{t-i} = \frac{\Delta Y_t}{\Delta R_{t-i}} = \frac{\Delta P_t}{\Delta R_{t-i}} \frac{\Delta Y_t}{\Delta P_t} = \beta_i \frac{\bar{P}}{\bar{R}} \cdot \frac{\Delta Y_t}{\Delta P_{t-i}} ,$$

Table 1. Equation (2) regression results

Explanatory Variable	Region									
	North-east	Lake States	Corn Belt	Northern Plains	Appala-chian	South-east	Delta States	Southern Plains	Mountain	Pacific
$W_t - \rho W_{t-1}$	0.0023	0.0014	0.0039	0.0042	0.0036	0.0038	0.0027	0.0049	0.0018	0.0003
	(3.7442)	(2.2904)	(7.6164)	(13.7280)	(5.0758	(5.4282)	(6.4858)	(8.7224)	(4.9086)	(0.7784)
$R_t - \rho R_{t-1}$	0.0009	0.0012	0.0007	0.0007	0.0011	0.0009	0.0018	0.0005	0.0018	0.0030
$R_{t-1} - \rho R_{t-2}$	0.0017	0.0023	0.0013	0.0013	0.0020	0.0017	0.0032	0.0010	0.0033	0.0054
$R_{t-2} - \rho R_{t-3}$	0.0023	0.0032	0.0018	0.0017	0.0028	0.0023	0.0044	0.0014	0.0044	0.0072
$R_{t-3} - \rho R_{t-4}$	0.0029	0.0039	0.0022	0.0021	0.0034	0.0029	0.0052	0.0017	0.0052	0.0084
$R_{t-4} - \rho R_{t-5}$	0.0033	0.0045	0.0025	0.0024	0.0039	0.0033	0.0056	0.0019	0.0057	0.0090
$R_{t-5} - \rho R_{t-6}$	0.0035	0.0049	0.0027	0.0025	0.0042	0.0035	0.0058	0.0020	0.0059	0.0090
$R_{t-6} - \rho R_{t-7}$	0.0036	0.0051	0.0028	0.0026	0.0044	0.0036	0.0056	0.0021	0.0057	0.0084
$R_{t-7} - \rho R_{t-8}$	0.0036	0.0052	0.0028	0.0025	0.0044	0.0036	0.0052	0.0021	0.0052	0.0072
$R_{t-8} - \rho R_{t-9}$	0.0035	0.0051	0.0027	0.0024	0.0042	0.0035	0.0044	0.0020	0.0044	0.0054
$R_{t-9} - \rho R_{t-10}$	0.0033	0.0049	0.0025	0.0021	0.0039	0.0033	0.0032	0.0019	0.0033	0.0030
$R_{t-10} - \rho R_{t-11}$	0.0029	0.0045	0.0022	0.0017	0.0034	0.0029	0.0018	0.0017	0.0018	
$R_{t-11} - \rho R_{t-12}$	0.0023	0.0039	0.0018	0.0013	0.0028	0.0023		0.0014		
$R_{t-12} - \rho R_{t-13}$	0.0017	0.0032	0.0013	0.0007	0.0020	0.0017		0.0010		
$R_{t-13} - \rho R_{t-14}$	0.0009	0.0023	0.0007		0.0011	0.0009		0.0005		
$R_{t-14} - \rho R_{t-15}$		0.0012								
$\sum_{i=1}^{n} \beta_i$ [b]	0.0365	0.0551	0.0280	0.0239	0.0438	0.0364	0.0461	0.0211	0.0469	0.0662
R^2	0.9111	0.9833	0.9859	0.9904	0.9912	0.9774	0.9237	0.9940	0.9937	0.9975
SEE[c]	0.03315	0.02595	0.03393	0.02851	0.03608	0.03965	0.04176	0.03979	0.02238	0.01927
DW[d]	2.29	2.08	1.89	2.08	2.16	2.07	2.15	1.74	1.84	1.45
ρ[e]	0.829	0.713	0.576	0.579	0.686	0.640	0.828	0.291	0.577	0.463

[a]Numbers in parentheses are t-values; all exceed the critical t value at the one percent level.

[b]A joint F test of the null hypothesis that all the regression coefficients for the R's are equal to zero was rejected at the one percent level of significance for all lag lengths.

[c]Standard error of the estimate.

[d]Durbin-Watson "d" statistic.

[e]The estimated value of the first-order autoregression coefficient of the disturbances.

where a bar over a variable indicates the average value of the variable and ΔY_t is the value of the agricultural output net of increases in the value of inputs.

To estimate the benefits of public investment in R&E, the marginal internal rate of return, i.e., that discount rate which equates the stream of marginal products with the initial investment of one dollar is computed for each of the ten farm production regions. The results are presented in Table 2.

It is apparent from Table 2 that marked differences in the rates of return to public R&E exist. The internal mar-

Table 2. Marginal internal rates of return (in percentages) to R&E

Region	Rate of Return	Region	Rate of Return
Northeast	20.0	Southeast	18.5
Lake States	43.0	Delta States	33.5
Corn Belt	33.5	Southern Plains	17.5
Northern Plains	28.5	Mountain	27.5
Appalachian	28.0	Pacific	54.0

ginal rates of return vary from a high of 54.0 percent in the Pacific region to a low of 17.5 percent in the Southern Plains.

SUMMARY AND CONCLUSIONS

The objective of this paper was to estimate historical rates of return to public sector R&E expenditures for each of ten farm production regions. A model which related the historical behavior of agricultural productivity in each region to current and past R&E expenditures, the level of educational attainment of farmers, and weather was hypothesized. The results of estimating this model for the 1939 to 1972 period indicate that the rates of return to R&E vary from 54.0 percent to 17.5 percent with a mean of 30.4 percent. This wide divergence between the rates suggests that a reallocation of funds among regions would increase the benefits to the nation as a whole.

REFERENCES

1. Allen, P. G., and R. E. Howitt. "The Allocation of Research and Extension Expenditures in Agriculture." Paper presented at American Agricultural Economics Association annual meeting, College Station, Texas, August 18-21, 1974.

2. Almon, Shirley. "The Distributed Lag Between Capital Appropriations and Expenditures." *Econometrica* 30 (January, 1956): 178-196

3. Cline, Philip L. "Sources of Productivity Change in United States Agriculture." (Ph. D. dissertation, Oklahoma State University, 1975).

4. Durbin, J. "Estimation of Parameters in Time-Series Regression Models." Journal of the Royal Statistics Society, Ser. B. 22 (January, 1969), 139-153.

5. Evenson, Robert E. "The Contributions of Agricultural Research and Extension to Agricultural Productivity." (Ph. D. dissertation, University of Chicago, 1968).

6. Griliches, Zvi. "Research Expenditures, Education, and the Aggregate Agricultural Production Function." *The American Economic Review,* 54 (December, 1964), 961-974.

7. Kost, William E. "Weather Indexes 1950-1963." *Quarterly Bulletin of Michigan Agricultural Station,* 47 (August, 1964), 18-42.

8. Lambert, L. D. "Regional Trends in the Productivity of American Agriculture." (Ph. D. dissertation, Michigan State University, 1973).

9. Latimer, R. G. and Paarlberg, "Geographic Distribution of Research Costs and Benefits," *Journal of Farm Economics* 47(May 1965): 234-241.

10. Schultz, T. W. "The Allocation of Resources to Research," in Walter L. Fishel (ed.), *Resources Allocation in Agricultural Research,* Minneapolis, Minnesota, University of Minnesota Press, 1971.

11. Stallings, J. L. "Indexes of the Influence of Weather on Agricultural Output." (Ph.D. dissertation, Michigan State University, 1958).

12. Theil, H. *Economic Forecasts and Policy,* 2d ed. Amsterdam: North Holland Publishing Co., 1961.

13. U.S. Department of Agriculture. Economic Research Service. *Changes in Farm Production and Efficiency.* Statistical Bulletin No. 233. Washington, D.C.: Government Printing Office, 1964 and 1973.