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An Analysis of Research Expenditures for Selected Agricultural Commodities

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Introduction

Benefits resulting from publicly provided research accrue not only to producers in the state in which the research is conducted, but may also spillover to producers in other states. This type of spillover from agricultural research expenditures is a form of externality because it occurs outside the market, i.e., the producers in other states do not pay for the research, although they benefit from its results. Although the pervasive nature of research, that is, its ability to spillover as benefits into other states, has been recognized, limited success has been achieved in measuring empirically the external effects of research expenditures (Peterson and Hayami). The overall objective of this paper is to measure the magnitude of externalities associated with agricultural research expenditures by states and to examine the implications of these externalities in the allocation process.

The organization of the paper is to first discuss the spillover specification used and its inclusion in a production function. The analytical framework is then developed. After that, the estimation procedure is outlined. The results of the estimation process and the calculated value marginal product of research spillovers are then reported. In the concluding sections, the results, an empirical application of the analytical framework, are presented.

Model Specification

A production function is specified to include conventional inputs and research expenditures. Peterson and Hayami (1977) note two major advantages of this approach. First, it allows for a rigorous test of the influence of agricultural research on agricultural output. Secondly, the value marginal product of research can be computed directly, since research expenditures are included as a variable within the production function. This relationship is complicated by the pervasive nature of research results. Public knowledge, with its potential to increase productivity, cannot be withheld from individual firms. Variables which will permit the calculation of the marginal effects of spillovers will be included in the production function.

The relationship is expressed in the form of a Cobb-Douglas production function. Following Bredahl and Peterson (1976), one can abstract from the time dimension in the analysis. This approach assumes that the current value of research expenditures can be used as a proxy over time. The basis for such a concept is the fact that allocations among commodity groups between states have been fairly constant over time (Peterson, 1969). The production function used in this study is:

$$(1)\quad Q_{hi} = A_h \prod_{j=1}^{m} X_{hij}^{\alpha_j} \prod_{k=0}^{n} R_{hik}^{\alpha_k}$$

where:

Q_{hi} is value of production of commodity h in state i,

X_{hij} is jth conventional input used in state i in production of h,

R_{hi0} is the expenditure being made on commodity h in individual state i,

R_{hi1} is the sum of expenditures being made on commodity h by states within the same production region as state i as defined by the Economics, Statistics and Cooperative Service, USDA,

R_{hi2} is the sum of expenditures being made on commodity h by states in production regions tangent to the region in question,

R_{hi3} is the sum of expenditures being made on commodity h by remaining states. $R_{hi3} = R_{hi*} - R_{hi0} - R_{hi2}$ where R_{hi*} is the total research expenditure being made on that commodity within the continental United States,

m is the number of conventional inputs,

n is number of regional groupings, and

α, β are production coefficients.

The variable R_{hi0}, which is simply the state's own research expenditure, is the same variable which was included in the production functions estimated by Bredahl and Peterson (1976). Its purpose is to give a means of measuring the effects on productivity accruing to a state as a result of its research expenditures. The variables R_{hi1}, R_{hi2}, and R_{hi3} account for spillovers and are based on the 10 production regions as delineated by the U. S. Department of Agriculture. The inclusion of these variables in the production function will allow for a means of calculating the marginal effects accruing to a state as a result of research expenditures made elsewhere. Under the hypotheses proposed in this study, expenditures in all states may have effects, albeit differential effects, on productivity in other states.

The Analytical Framework

When available resources are limited, a necessary condition for maximum economic efficiency is achieved by allocating expenditures among the research areas in such a manner that the resulting values of marginal product are equal (White, 1980). The equi-marginal principle, stated above, is generally accepted. Consideration should be given to the variables which can be used in calculating the value of marginal products. There are two alternatives that decision makers might consider. The first alternative involves finding the efficient allocation of research expenditures when only internal benefits are considered. The second alternative, which is more desirable from society's point of view, takes into consideration internal benefits and benefits generated by the state under consideration, but which spillover to other states.

The first alternative, which is optimum for the state, equates the value of marginal products of research, $VMPR_{1i} = VMPR_{2i} = \ldots = VMPR_{hi}$.

The VMPRs measure only the benefits accruing to the state conducting the research, which includes spillins from other states. Here $VMPR_{hi}$ can be defined as

$$(2)\quad VMPR_{hi} = \frac{\beta_1 Q_{hi}}{R_{hi1}} = \frac{\beta_1 C_{hi} R_{hi1}^{\beta_1} \prod_{k=2}^{n} R_{hik}^{\beta_k}}{R_{hi1}}$$

where

$$C_{hi} = A_h \prod_{j=1}^{n} X_{hij}^{\alpha_j}.$$

The research variable R_{hi1} represents internal expenditures, while the remaining $\prod_{k=1}^{n} R_{hik}^{\beta_k}$ accounts for spillins. This situation is characteristic of a state operating in its own best interest, while ignoring benefits generated by its research that accrues to other states.

The second alternative is desirable from the nation's perspective, since the calculation of the $VMPR_{hi}$ by the state includes not only benefits to the state conducting the research, but also benefits to other states. Here

$$(3)\quad VMPR_{hi} = \frac{\beta_1 C_{hi} R_{hi1}^{\beta_1} \prod_{k=2}^{n} R_{hik}^{\beta_k}}{R_{hi1}} + \sum_{k=2}^{n} \sum_{p=1}^{S_j} \frac{\beta_k C_{hp} R_{hp1}^{\beta_1} \prod_{k=2}^{n} R_{hik}^{\beta_k}}{R_{hik}}$$

with

$$C_{hp} = A_h \prod_{j=1}^{n} X_{hpj}^{\beta_j}$$

and where

S_2 are states in same region,

S_3 are states in adjacent regions, and

S_4 are states in non-adjacent regions.

The second term in this expression can be attributed to spillouts. The desirable allocation for the nation would occur where the resulting $VMPR_{hi}$'s are equal.

The Estimation Procedure

The production function as given in equation (1) can be estimated in logarithmic form by ordinary least squares regression analysis. There exists, however, the potential problem of mutlicollinearity among the research variables. In light of this problem an alternative approach to the estimation process will be suggested.

A traditional means of dealing with the problem of multicollinearity is to introduce prior information in the form of restrictions, thereby reducing the number of parameters to be estimated. In this study spatial application of the polynomial structure will be made. Within the context of the model, the weights will be noted as β_k and are assumed to be values of an unknown function, say f(k), k = 0, 1, ..., n, where n is the maximum number of regional groupings (4 in this case). With only four regional groupings, it is hypothesized that the relationship among the research variables is linear, i.e., a polynomial of degree one. It has been shown by Hill and Johnson (1976) that the constraints imposed by the model are in fact linear independent restrictions which can be imposed directly using a restricted least squares (RLS) estimator.

The Estimation Results

Production functions were estimated for dairy and cash grain farms. The unit of observation was the average farm in each state with pooled data for 1969 and 1974. For a thorough discussion of data sources and variable specification, see Garren (1981). These production functions were estimated by restricted least squares as described above. Of general consideration is the testing for the polynomial degree. For both cash grains and dairy, the hypothesis, that the polynomial degree equals one, is not rejected. The estimation results are presented in Table 1.

A second consideration was the inclusion of the intercept dummy variable to account for structural shifts between the two years 1969 and 1974. The dummy variable used had a zero value for 1969 and a one value for 1974. In the case of both commodity groups, the estimate for the dummy variable was statistically significant. The coefficients are presented with the estimation results.

The cash grain production function performed well. With the exception of the seed variable, all the conventional inputs had positive coefficients as anticipated (see Table 1). The estimates are consistent with Bredahl and Peterson (1976) and Norton (1980). The largest coefficient was .497 for land. The coefficients on the labor, machinery, fertilizer and chemical variables ranged from 0.10 to 0.20. The seed coefficient was statistically insignificant. Of particular interest are the research coefficients. All are positive and significantly different from zero. The coefficient for R_0, the state's own research expenditure, is .049. The coefficients for the three spillin variables, R_1, R_2, and R_3 are slightly larger than R_0, being .07, .09 and .111, respectively.[5/]

The production function for dairy also performed well (Table 1). Only the pasture variable in dairy was not statistically significant. The coefficients on the other conventional inputs ranged from 0.11 to 0.36. Again, the focus is on the research variables. All these variables are positive in the dairy equation, and R_0 through R_2 are significantly different from zero. In terms of relative magnitude the results are different from cash grain. R_0 at .058 is the largest, with R_1 through R_3 becoming sequentially smaller, being .049, .040, and .031, respectively.

Table 1. Estimated Production Functions for Average Cash Grain and Dairy Farms[a]

Inputs	Restricted Least Squares	
	Cash Grain	Dairy
Land	.497 (7.05)	.111 (2.62)
Labor	.115 (1.47)	.251 (3.11)
Machinery	.178 (1.15)	
Fertilizer	.196 (4.42)	
Chemical	.103 (1.39)	
Seed	-.083 (-.84)	
Cows		.263 (2.49)
Pasture		-.007 (-0.14)
Feed		.361 (3.54)
Livestock		
R_0 - Research expenditures within the state	.049 (2.15)	.058 (2.55)
R_1 - Research expenditures within the production region	.070 (5.63)	.049 (5.69)
R_2 - Research expenditures within adjacent production regions	.090 (5.44)	040 (2.58)
R_3 - Research expenditures within non-adjacent production regions	.111 (3.73)	.031 (0.97)
Structural shift dummy variable for 1974	-.200 (-2.71)	.294 (5.18)

[a]Student t-values are given in parentheses.

The Value Marginal Product of Research

One means of interpreting the estimation results is to examine the value marginal product of research (VMPR) for each of the four research categories. The estimated coefficients are used to compute the national "average" value marginal products of agricultural research. To obtain a national average VMPR the geometric means of the value of production and research for dairy and cash grain for the nation are used.

For both of the commodities, the value marginal product of research within the state ($VMPR_0$) is the largest. For cash grain, the $VMPR_0$ is $15.18, while for dairy, it is $13.68. The value marginal product of the three spillin variables $VMPR_1$, $VMPR_2$, and $VMPR_3$, become sequentially smaller. These values range from $5.88 to $1.20 for cash grain and from $2.03 to $0.23 for dairy. When measured in terms of productivity, the dollar of research expenditures within the state generates the largest increase in productivity. The dollar expenditure by states in the same production region generates the next largest increase. The third largest increase in productivity is generated by the dollar expenditure made by the adjacent regions. Even the dollar expenditure made by the rest of the nation generates increases in productivity within a state for cash grains and dairy.

Efficient Allocation of Agricultural Research Expenditures

The estimation results reported in Table 1 were used in conjunction with actual observations on conventional inputs in all states to determine efficient allocation of research expenditures between cash grains and dairy in each state. The total funds available to a state for allocation among dairy and cash grains is set by the sum of its 1974 research expenditures on these two categories. Then two efficient solutions were determined for each state.

First, spillins were considered but spillouts were ignored. This alternative is represented by equation (2) and reflects states operating in their own best interest. Secondly, both spillins and spillouts are taken into account. This alternative, which is represented by equation (3), would be more desirable from the nation's perspective.

Instead of presenting the results of each alternative, ordinary least squares will be used to estimate equations for dairy, with the relative importance of dairy to a state as the independent variable and the percentage of funds efficiently allocated to dairy as the dependent variable. The equation for dairy, estimated from the results of the first alternative, is as follows:

$$(4) \quad PRED = \underset{(5.12)}{1.69} + \underset{(149.02)}{1.01}\ PRID$$

where:

PRED = the percentage of research expenditures allocated to dairy, and

PRID = the percentage of relative importance of dairy to the state. The numbers in parentheses are Student t-values. The equation for dairy, estimated from the results of the second alternative, is as follows:

$$(5) \quad PRED = \underset{(19.20)}{46.9} + \underset{(11.39)}{.50}\ PRID$$

where:

PRED = the percentage of research expenditures allocated to dairy, and

PRID = the percentage of relative importance of dairy to the state.

Equations (4) and (5) are graphed in Figure 1.

For a state in which dairy production is low relative to cash grains, consideration of spillins only as depicted by curve A would allocate less to dairy research than would be desirable from the nation's perspective as depicted by curve B. On the other hand, if dairy production is relatively important in a state, then consideration of spillins only would result in a greater allocation of expenditures to dairy research than would be warranted from the nation's perspective.

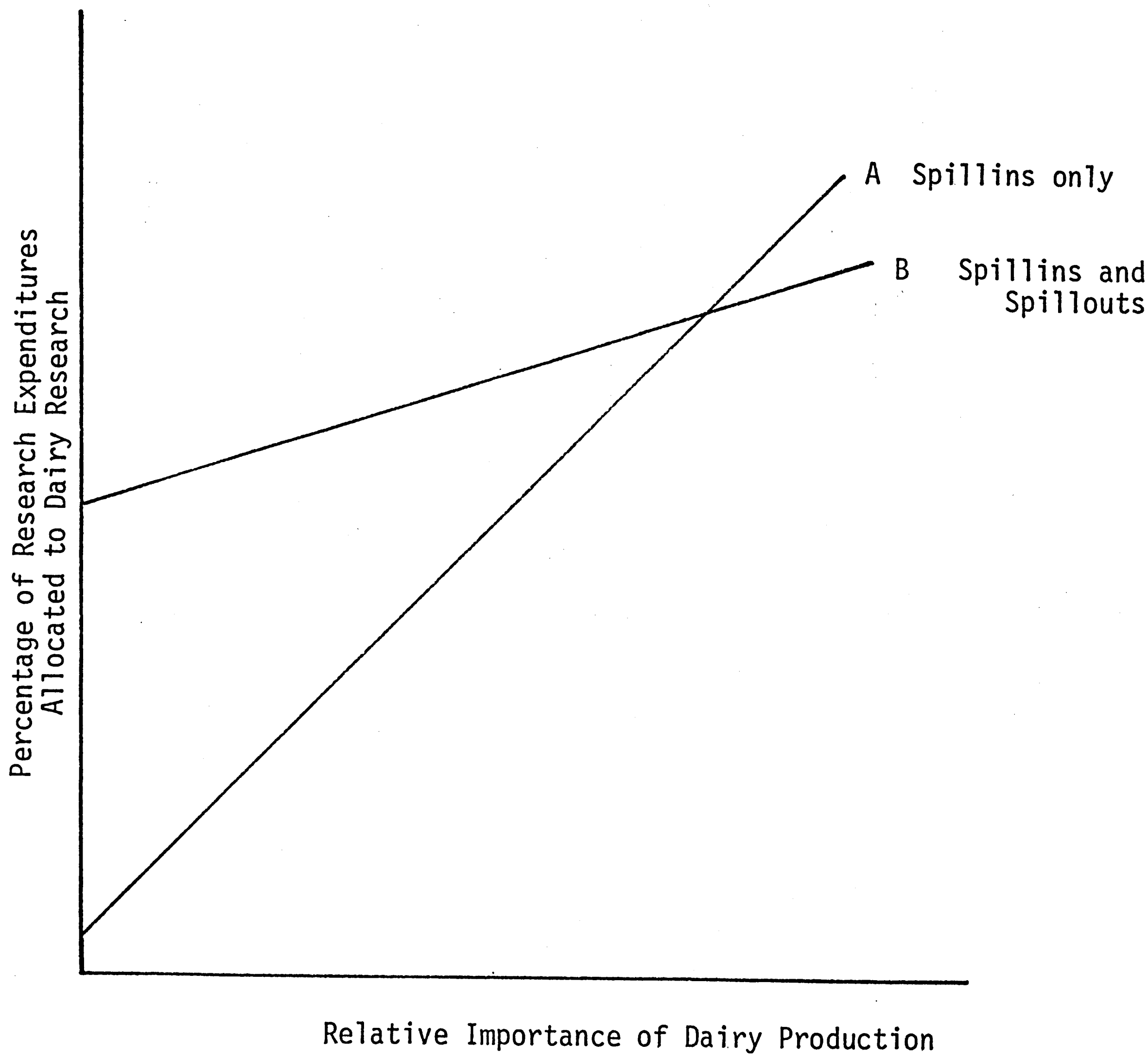

Figure 1. Allocation of a State's Research Expenditures to Dairy Research

Conclusion

The results of this study indicate the presence of externalities in agricultural research expenditures. Although the greatest increase in productivity from an expenditure would occur within the state, spillovers had a statistically significant impact on productivity in other states. These results have important implications for interpreting the results from other studies that ignored externalities. By attributing all increases in productivity within a state solely to research expenditures within that state, the results from such studies would seriously bias the estimates of the value marginal product of research.

The presence of externalities also has implications in the expenditure allocation process. The consideration of externalities in the allocation of research funds is an extension of the analytical framework developed elsewhere to assure efficient allocation. Externalities are only one of many considerations in the decision making process, but as such they have a measurable effect on the efficient allocation of research funds. The framework developed in this paper suggests th need to consider both spillins and spillouts in relationship to the commodity's relative importance in the different states. The inclusion of spillins only in the analysis is sufficient for the state desiring to act simply in its own best interest. For the state to act in a manner that would be desirable from the nation's perspective, spillouts must also be included. These results have important implications for coordination of research among states so as to achieve efficient allocation of research expenditures relative to the nation's perspective rather than each individual state's perspective.

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