IMPACTS OF PUBLIC RESEARCH EXPENDITURES ON AGRICULTURAL VALUE-ADDED IN THE U.S. AND THE NORTHEAST

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ABSTRACT

This paper illustrates differences in estimated returns to public agricultural research investments for the U.S. and the Northeast when value-added (VA) as opposed to gross production (GP) functions are estimated. Commodity groups considered are dairy, poultry, other livestock, and cash grains. Sizable differences are evident in returns estimated with VA as opposed to GP functions, with the VA estimates generally being larger. Cash grains research yields the largest returns at the margin. Dairy research is more productive in the Northeast than the rest of the country.

INTRODUCTION

The concept of "value-added" has been widely applied to the manufacturing sector but seldom to the farming sector. Value-added is the difference between the value of the final product and the value of inputs consumed to produce that product. It is the wealth that accrues to the economy as returns to labor-management, the stock of durable capital, and the land base when the commodity is produced. Research and Extension (R&E) related to agricultural production are designed to enhance the creation of this wealth. As such, the created wealth provides the major justification for R&E funding (Kunz and Purcell, 1981). As industrial inputs and interfarm transfers of inputs become increasingly important in the farm sector, knowledge of value-added (VA) as opposed to gross production (GP), and likewise the impact of R&E on VA as opposed to GP, become increasingly important for R&E allocation decisions.

The purpose of this paper is to illustrate differences in estimated returns to public agricultural research investments for the U.S. and the Northeast when VA functions are estimated as opposed to the more commonly used GP functions. Commodity groups considered are dairy, poultry, other livestock, and cash grains. Estimates of value-added used in the analysis are those values created by on-farm production processes as reported in Kunz and Purcell (1981).

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METHODS

Estimation of value-added as opposed to gross production functions has a number of advantages. One is the improved comparability of data for individual commodities when the degree of vertical integration among the commodities differs. A second is the reduction in double counting of inputs when the output of one product enters into the production of a second product. A third is that short-run changes in the demand for a commodity may not change the level of use of land, capital, or operator labor, but may cause a significant change in the levels of consumed inputs such as fertilizer or energy inputs. In this sense consumed inputs are more endogenous than other inputs and their use as independent variables is more likely to lead to biased estimators if standard least squares procedures are used to estimate a GP function. A fourth advantage is that removal of consumed inputs as independent variables in the regression equations may reduce multi-collinearity problems.

The value-added function also requires certain restrictive assumptions. To justify subtracting consumed inputs from both sides of a GP function when constructing a VA function, the use of nonconsumed inputs in production must be separable from consumed inputs. If Q is a gross output of the commodity and K, L, N, and M stand for capital, labor, land and consumed inputs respectively, a GP function can be represented by,

(1) $Q = q(K, L, N, M)$.

The notion of value-added which equals Q-M has meaning in a production function framework only if equation (1) can be assumed to take on the nested form,

(2) $Q = q[V(K, L, N), M]$.

This requires the marginal rates of substitution between K and L, K and N, and N and L in the production of Q to be independent of M (i.e., K, L, and N cooperate to produce an intermediate good, VA, which then cooperates with M to produce Q). This is a testable hypothesis.

The VA function also requires that the coefficients of consumed inputs be constant across observations. If the consumed-input coefficients remain constant, consumed inputs are being used in fixed proportion to output. Furthermore, under a profit maximization where the value of marginal product of each input equals its price, the amount of consumed inputs used vary in proportion to gross output if the consumed input-output price ratio remains constant. Thus if producers behave in a profit maximizing manner, the replacement of GP by VA can be justified.

Four GP functions (one for each commodity group) and four VA functions were estimated. The general form of the GP functions is the following

Cobb-Douglas function:

$$(3)\quad Q_t = A \prod_{i=1}^{m} X_{it}^{B_i} \prod_{j=0}^{n} R_{t-j}^{\alpha_{t-j}} e^{u_t}$$

where,

Q_t = value of output per farm in year t
A = a shift factor
X_{it} = the i^{th} conventional input per farm in year t
R_{t-j} = the expenditure on research per state in year t-j
u_t = a random error for year t
B_i, α_{t-j} = production coefficients.

The general form of the VA functions is,

$$(4)\quad V_t = A \prod_{i=1}^{m-c} X_{it}^{B_i} \prod_{j=0}^{n} R_{t-j}^{\alpha_{t-j}} e^{w_t}$$

where,

V_t = value-added per farm in year t by the production process
w_t = a random error for year t.

Other variables are identical to those defined for the GP functions except that there are m-c conventional inputs where c = the number of consumed inputs.

These functions are estimated by ordinary least squares methods. Marginal products and internal rates of return to agricultural research are calculated and the validity of the value-added specification is tested.

VARIABLES AND DATA

All except research variables were included on a per farm basis because the farm is the decision making unit. Research variables were measured on a per state basis to reflect the "public good" nature of research. Research used by the farm within a state does not reduce research available to another farm within a state. The weather variable in the cash grains functions was measured as deviations from normal July rainfall[1] and is not expressed in logarithms.

The major sources of data for the nonresearch variables were the 1978 Census of Agriculture with price deflations and other adjustments made with data obtained from USDA publications Agricultural Prices, 1978 Annual Summary, Farm Labor, Farm Real Estate Market Development, Commercial Fertilizer, and Meat Animals. State Agricultural Experiment Station research expenditures were obtained from Volume II of the Inventory of Agricultural Research for the years 1967 to 1978.

The dependent variable for the value-added functions is obtained by taking the state gross value of output for specific commodities and adjusting by value-added factors obtained from Kunz and Purcell (1981). Because the commodity groups are made up of several commodities, it was necessary to use these data to construct a weighted value-added factor for each commodity group and to multiply that by the gross output value for that group.

Except for agricultural research, all data are cross-sectional for the year 1978. Agricultural research is incorporated into the functions as a twelve year second order Almon polynomial distributed lag using data from 1967-1978. The main justification for using this particular lagged structure was to capture the initially increasing and eventually declining impact of research on output. The length of lag is consistent with previous studies by Evenson (1968) and others. A complete description of all data sources and variables can be found in Smith (1982).

REGRESSION RESULTS

Regression results obtained from estimating GP and VA functions for cash grains, poultry, dairy, and other livestock are shown in Tables 1 and 2. Most nonresearch coefficients were significant at the .05 level with some notable exceptions in the cash grains and poultry functions.

Coefficients of the research variables were significant at the α = .05 level in both the GP and the VA cash grains functions as measured by t-values, but were nonsignificant in both dairy functions. They were significant in the VA but not the GP livestock functions and vice versa for the poultry research coefficients. Several reasons may exist for nonsignificance of certain research coefficients. One is the importance of research spillovers across state lines. States with a relatively low amount of research may have borrowed from neighboring states to the point that they are just as productive. It is the lag in borrowing that allows one to measure a return to research in cross-sectional studies.

An attempt was made to capture research spillover effects. A spillover variable was calculated for each commodity group by summing research expenditures for a commodity group across all states and then subtracting research expenditures for state i to get research expenditures outside of state i. The Almon time weighting was then applied. Re-estimating the above equations with this admittedly crude spillover variable resulted in negative and/or nonsignificant research spillovers.

Comparisons can be made among research coefficients obtained in the GP functions and those obtained in a previous study by Bredahl and Peterson (1976) using 1969 Census of Agriculture data and by Norton (1981) using 1974 census data.

[1] For cash grains the specifications of the GP and VA functions differ slightly from (3) and (4). Letting the weather variable be X_1, the specification of the GP function is:

$$Q_t = Ae^{\beta_1 x_{1t}} \prod_{i=2}^{m} x_{it}^{\beta_i} \prod_{j=o}^{n} R_{t-j}^{\alpha_{t-j}} e^{u'_t}$$

and the specification of the VA function is:

$$V_t = Ae^{\beta_1 x_{1t}} \prod_{i=2}^{m-c} x_{it}^{\beta_i} \prod_{j=0}^{n} R_{t-j}^{\alpha_{t-j}} e^{w'_t}.$$

where u'_t and w'_t are random errors for year t and the other variables are the same as in (3) and (4).

Table 1. Estimates of Cash Grains, Dairy, Livestock, and Poultry Gross Production (GP) Functions.

Inputs	Cash Grains	Dairy	Livestock	Poultry
Fertilizer	.048 (.43)[a]			
Seed	.151 (1.37)			
Chemicals	-.114 (.88)			
Labor	.319 (2.02)	.067 (1.72)	.167 (2.06)	.039 (1.08)
Land & Buildings	.465 (3.81)	.092 (1.80)	.440 (3.93)	-.160 (2.53)
Machinery	.080 (.33)			
Weather	.040 (1.21)			
Feed		.651 (7.60)	.073 (2.28)	1.105 (11.88)
Cows		.304 (3.01)		
Pasture		-.079 (2.47)		
Breeding Stock			.483 (5.43)	
Poultry				-.075 (1.42)
Research	.115 (2.05)	-.001 (.06)	.037 (.58)	.068 (1.89)
Sum of Coeffieients[b]	.989	1.035	1.163	.909
$\bar{R}^2$ [c]	.93	.98	.92	.95

[a]Figures in parentheses are t-values with 48 observations for cash grains, dairy, and livestock; 43 observations for poultry.

[b]Excluding the research coefficient.

[c]$\bar{R}^2 = 1 - \left[\left(\frac{n-1}{n-k-1}\right)\left(1-R^2\right)\right]$ is the coefficient of determination adjusted for degrees of freedom.

Variable construction in the present study followed those previous studies as closely as possible. However, because of several changes in the 1978 Census of Agriculture the results are not strictly comparable. Nonetheless, Table 3 shows the research coefficients from all three studies. Only in the cash grains commodity group is the research coefficient significantly different from zero in all three periods. The research coefficients of the 1978 dairy and livestock functions differed significantly from their 1969 and 1974 counterparts while the research coefficient for the 1978 poultry function was very close to the 1969 coefficient.

In order to test for possible differences in the production elasticities of research between the Northeastern states and the rest of the U.S., the 1978 GP and VA functions were re-estimated using zero-one variables to allow for variable slopes of the research variables (Northeastern states = 1 and states in other parts of the U.S = 0). The estimated coefficients and t-values for the zero-one shifters are shown in Table 4. Except for dairy, none of the coefficients of the zero-one variables were significantly different between the Northeast and the rest of the U.S. Dairy research in the Northeast appears to be more productive than in the rest of the U.S.

Two tests were conducted to determine the validity of the VA as opposed to the GP function specification. The first test, developed by Griliches and Ringstad (1971), tested if consumed inputs were separable from nonconsumed inputs and if consumed inputs are used in fixed proportion to output. The results indicate that value-added may legitimately be used. A second test suggested by Davidson and MacKinnon (1981) to test the appropriateness of one econometric model in the presence of one or more alternative models was also applied. The results indicated that

Table 2. Estimates of Cash Grains, Dairy, Livestock, and Poultry Value-Added (VA) Functions.

Inputs	Cash Grains	Dairy	Livestock	Poultry
Operator Labor	.083 (.67)[a]	.158 (1.63)	.289 (2.86)	.315 (2.19)
Land & Building	.566 (4.60)	.366 (2.95)	.264 (2.11)	-.310 (1.04)
Machinery (Fixed Cost)	.284 (2.17)			
Weather	.066 (1.89)			
Cows		.690 (5.95)		
Breeding Stock			.637 (6.71)	
Poultry				.459 (3.48)
Research	.190 (5.28)	-.003 (.07)	.138 (3.54)	.135 (.74)
Sum of Coefficients[b]	.999	1.214	1.190	.464
$\bar{R}^2$	.92	.85	.89	.34

[a]Figures in parentheses are t-values with 48 observations for cash grains, dairy and livestock; 43 observations for poultry.

[b]Excluding research coefficient.

[c]$\bar{R}^2 = 1 - \left[\left(\frac{n-1}{n-k-1}\right)\left(1-R^2\right)\right]$ is the coefficient of determination adjusted for degrees of freedom.

Table 3. Estimates of Research Coefficients from Gross Production Function Studies Using 1969, 1974, and 1978 Data.

Commodity Group	1969	1974	1978
Cash Grains	.073 (2.72)[a]	.091 (3.68)	.115 (2.03)
Dairy	.041 (2.62)	.057 (3.12)	-.001 (.06)
Poultry	.071 (1.84)	.017 (.52)	.068 (1.88)
Other Livestock	.122 (4.69)	.168 (6.98)	.037 (. 58)

[a]Numbers in parentheses are t-values.

Table 4. Research Slope Coefficients For the Northeast[a]

Commodity Group	GP Function Research Dummy		VA Function Research Dummy	
Cash Grains	-.002	(.17)	.010	(.67)
Poultry	.006	(1.57)	.029	(1.49)
Dairy	.010	(2.84)	.025	(2.75)
Livestock	-.018	(1.15)	-.015	(.74)

[a]States included are Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, Delaware, New Jersey, Maryland, and West Virginia. The rest of the U.S. is the reference; i.e. the discrete variable takes on a value of zero.

[b]Numbers in parentheses are t-values.

either the GP or the VA functions could be used. Details on these tests are found in Smith (1982).

MARGINAL PRODUCTS AND RATES OF RETURN

The estimated research coefficients from both the GP and the VA functions are used to calculate marginal products and marginal internal rates of return to agricultural research. The national average marginal product of research for each commodity group is:

$$MPR = \sum_{j=0}^{n} \hat{\alpha}_{t-j} \bar{f} \; (\bar{Y}/\bar{R}),$$

where $\bar{f}$ is the arithmetic average number of farms for each commodity group, $\hat{\alpha}$ is the corresponding partial research coefficient lagged j years, $\bar{R}$ is the geometric mean level of per state research, and $\bar{Y}$ is the geometric mean level of per farm gross output or value-added.

The estimated marginal products of agricultural research are presented in Table 5 and approximate the long-run return from one dollar invested in research in 1978. The MPR for the dairy functions are only for the Northeast while the MPR for the other functions are for both the Northeast and the rest of the U.S.

To convert the returns to an annual basis, the marginal products were distributed over twelve years using the estimated second order polynomial distribution. Internal rates of return (r_R) were calculated using the following equation:

$$[\sum_j \; (MPR_{t-j}/(1+r_R)^j] - 1 = 0.$$

The results shown in Table 5 indicate sizable differences in returns across commodity groups as well as between GP and VA functions. While the nonsignificance of certain research coefficients needs to be kept in mind, the increase in the cash grains rate of return and the decrease in the poultry rate of return when moving from the GP to the VA functions indicate the importance of considering value-added. Also, with the exception of poultry, rates of return to research are higher for the VA than the GP functions. This may indicate a higher payoff to the last dollar invested in improving nonconsumed as opposed to consumed inputs.

Results from both the GP and VA functions show that highest returns come from cash grains research. Furthermore, the returns are significantly higher for this group than those obtained by Bredahl and Peterson (1976) and by Norton (1981), but similar to those obtained by Otto (1981). Several factors can cause these rates of return to vary including differences in research coefficients, output values, research expenditure and the assumed research lag. All of these may be causing the differences noted above.

CONCLUSIONS

One of the strongest and most general conclusions which follows from the above analysis is the need to exercise caution when attaching significance to a particular rate of return to research estimated in an individual study. Sizable differences are evident in returns estimated from VA as opposed to GP functions. Differences also occur across years for reasons previously noted. Returns to research across commodity groups can change markedly when relative output prices change.

Results in this study indicate that dollars invested in cash grains research return the most at the margin. It appears that northeastern dairy research may be more productive than dairy research elsewhere in the U.S. Research productivity for other commodity groups is similar between the Northeast and the rest of the U.S.

With the exception of poultry research, it appears that additional research aimed at improving productivity of nonconsumed inputs may be more productive than research aimed at consumed inputs. This conclusion is particularly appro-

Table 5. Marginal Products and Marginal Internal Rates of Returns to Experiment Station Research

Commodity Group	Gross Production Function		Value-Added Function	
	MP (1978$)	IRR (%)[c]	MP (1978$)	IRR (%)[c]
Cash Grains[a]	95.8	202.0	103.7	307.9
Dairy[b]	9.78	24.87	14.78	38.78
Poultry[a]	24.1	60.9	9.8[d]	25.5[d]
Other Livestock[a]	8.7	22.3[d]	16.5	43.3

[a]For the Northeast and the U.S.

[b]For the Northeast alone.

[c]Following Bredahl and Peterson and Norton, to arrive at conservative estimates of rates of return, the marginal products in Table 5 were divided by three to take account of public extension and private research before calculating the IRRs.

[d]Calculated from nonsignificant research coefficients at the $\alpha = .05$ level.

priate for state decision makers interested in increasing the wealth within their states, and perhaps less appropriate for federal decision makers. The poultry results may indicate a higher return to research aimed at improving feed efficiency as compared to research aimed at nonconsumed inputs.

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