Miscellaneous Publication 8--1981
Minnesota Agricultural Experiment Station
University of Minnesota

Evaluation of Agricultural Research

Proceedings of a Workshop Sponsored by NC-148
Minneapolis, Minnesota May 12-13, 1980

SOME PRELIMINARY RESULTS OF ESTIMATING THE IMPACTS OF RESEARCH INVESTMENT ON CORN, WHEAT AND SORGHUM

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Introduction

The aggregate approach to the evaluation of production oriented expenditure in the United States has consistently shown high rates of return to agricultural research investments. These efforts, while showing the value of agricultural research, are limited in the information they can provide policy and budget decisionmakers. More recently, efforts such as the analysis of four major commodity groups by Bredahl and Peterson and cross sectional studies by Evenson, White, and Havlicek have begun refining the level of analysis to individual regions and states and for specific commodities (Evenson, Bredahl and Peterson, White and Havlicek).

The objective of this study is to further disaggregate these commodity groupings of Bredahl and Peterson into individual commodities and to begin investigating the impact of interregional research "spillovers." Case studies of corn, wheat, and sorghum are made, using individual states as observation units over the time period for which research data on individual commodities are available. The empirical results presented in this paper are the results of some first attempts at estimation. Further work is being done to improve specification of variables measuring weather, cash inputs, risk, and other factors influencing yield response of grain commodities. A special cross sectional-time series algorithm is used in parameter estimation.

Theoretical Framework, Model, and Data

The conceptual framework of this study is particularly constrained by the availability of only 11 years of research expenditure data on individual commodities (1967-1977). The short number of years prohibits use of a 12-, to 13-year polynominal Almon distributed lag which has been used in previous studies to investigate the research lag structure (White, et al., Quance and Lu). The nonavailability of production input data for specific commodities for other than farm census years also limits utilizing the traditional aggregate production function approach to the analysis of agriculture research expenditure.

Faced with these data limitation problems, the framework of a supply response analysis is developed as an alternative to investigating the impact of research expenditures on productivity of individual grain commodities. The supply response model which is derivable from the production function, expresses the quantity of a commodity offered for sale as a function of input and output prices, technical parameters, and a variety of shifters, such as weather and technological change. Supply analysis studies have typically represented the effects of technological change as a linear trend variable. While the research evaluation studies have not focused on the processes of technological adoption and diffusion, their analyses have shown that public investments in agricultural research activities have contributed to increases in productivity. On this basis, lagged research expenditures on individual commodities will be used as the technological change shifter in the commodity response functions.

The Model

The general supply function for a particular commodity can be written as:

$$(1) \quad Q = f(PF, PQ, L)$$

where output (Q) is a function of price of the variable inputs (PF), price of the output (PQ) and the already decided land input (L). Under assumptions of profit maximizing behavior, which

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requires the marginal physical product of inputs to be equated to the ratio of input-product prices, the ratio of PF/PQ can also be used.

This specification of the supply function uses as its dependent variable, total output, which is based on yield per acre (Q/L) and total acreage components. The land, or acreage component of this function is typically used in supply response estimation and is influenced by economic, political, and environmental factors such as expected prices, government programs, and crop rotational requirements. The second component (Q/L) is affected by the level of fertilizer and other input used, along with the shifters such as weather and technological change. Since this second component better isolates the impact of technological change, via research investment, and is also a more precise measure of productivity change, this study will focus on explaining changes in yield per acre.

Estimating Equation and Data

The theoretical development of the previous section provides the basis for a more complete specification of factors influencing yields and the variables used in estimating yield response functions for corn, wheat, and sorghum. Data on these commodities were for the 1972-78 crop years with research expenditures lagged an additional four and five years to the beginning of that data series. The following is a general statement of the basic model actually used to estimate yield response equations for corn, wheat, and sorghum:

$$(2) \quad (Q/L) = g(PF, PQ, L, W, \Delta A, R, OR)$$

where (Q/L) is yield per acre of each commodity, (PF) is the price of fertilizer, (PQ) is the price of output, (L) is harvested acres, (W) is the weather variable, (ΔA) is the change in farm machinery assets, (R) is in-state research on a particular commodity, and (OR) is outside research on a particular commodity. A more detailed description of these variables is presented in Appendix Table A. The observations on these variables were drawn from a six-year time series for all commodities with cross sections of 23 states for sorghum, 36 states for wheat, and 39 states for the corn analysis.

Estimation Procedure

The cross section-time series nature of the data used in this study presents potential statistical problems to efficient parameter estimation. Within a pooled data sample, the nature of the disturbance between two states at some specific point in time may differ from the disturbance of a specific state over different points in time. Various specifications of the behavior of the pooled disturbance terms have been discussed and used by Balestra and Nerlove, Fuller and Battese, Parks and others (Kmenta). this study will be using the approach developed by Parks which combines the assumptions frequently made about cross sectional observations with those usually made concerning time series observations. Time series analysis often assumes that the disturbance terms are autoregressive, while cross sectional data frequently assumes that the disturbances are mutually independent and heteroskedastic. When the observational unit is a state which can cut across geoclimatic regions, the assumption of mutual independence may not be satisfied. The Parks model is a cross-sectionally correlated and time-wise autoregressive procedure useful in cases where the assumption of mutual independence is not made. This estimation procedure is used to estimate parameters of the models.1/

Empirical Results

Several variations of the general model in (2) were developed and tested using the Parks method of estimation from pooled cross sectional time series data. The usual summary statistics presented in Tables 1 and 2 differ from OLS results in several ways. By accounting for serial correlation, heteroskedasticity and non-zero covariances, individual parameter estimates have been made more efficient. Also, in terms of R^2 values, the Parks procedure, which is a GLS method, can do no better than the pooled OLS models which minimizes Sum of Squares Errors to obtain BLU Estimates. The R^2 values presented along with the results are from the pooled OLS estimates and can be interpreted as approximations of the explanatory power of these models. The yield models are all linear functions of prices and other variables.

Preliminary results for these models, estimated using the Parks method, are presented in Tables 1 and 2. Although the regression equations are significant, the results for the wheat and sorghum models indicate that a rather low proportion of the variation in yield per acre and absolute annual changes in yield were explained by the model. The combination of cross sectional and time series data exhibited large variations in yield levels ranging from 24 to 126 bushels per acre for corn, 13.2 to 75 bushels per acre for wheat, and 16 to 87 bushels per acre for sorghum. Attempts were made to deal with variations in yields due to possible classification of states through introduction of indicator variables for geographical regions and for states which are relatively small producers of these commodities (less than 100,000 acres). These classification efforts had mixed degrees of success. The dummy shifter for small producing states indicated higher levels of corn yields in

Table 1.
Results of Yield per Acre Functions for Wheat, Sorghum, and Corn Using Park's Method for Pooled Cross-Sectional and Time Series Data

	Constant	$\frac{PF_{t-1}}{PO_{t-1}}$	PF_{t-1}	PO_{t-1}	Sept. Weather	Har. Acres	Weighted Land	Irr. Acres	Change in M. Assets	Res.	O.S. Res.	D1	D1* O.S. Res.	R^2
Wheat 36 states	52.71 (3.19)		-.092 (1.88)	.766 (.712)	.055 (1.21)	-.0036 (7.04)		.619 (1.56)	.0021 (.503)	.032 (6.36)	-.0061 (1.56)	-18.4 (.82)	.005 (.55)	.28
Wheat 36 states	53.32 (3.22)	-.087 (1.93)			.065 (1.63)	-.0031 (6.91)	.418 (7.63)	1.41 (3.65)	.010 (2.84)	.027 (5.86)	-.0045 (1.16)		-.0017 (2.43)	.27
Corn 39 states	-24.14 (1.73)		-.261 (3.93)	-.111 (2.78)	.329 (3.14)	.0040 (4.62)		.646 (9.28)	.0094 (1.14)	-.026 (2.56)	-.0047 (1.03)	32.02 (1.5)	-.0083 (1.32)	.648
Corn 39 states	27.52 (1.76)	.030 (.33)			.352 (6.26)	2.71 (2.24)	.100 (.596)	5.24 (3.11)	.0038 (.60)	.0081 (.73)	.0027 (.64)		.0043 (.26)	.67
Sorghum 23 states	75.05 (5.44)		-.26 (3.26)	-.301 (.91)	.133 (.799)	-.0013 (1.31)		.379 (5.33)	(.0027) (.11)	.0078 (.340)	.421 (.658)			.22

Numbers in parentheses are t values.

Table 2.
Results of Changes in Yield per Acre for Sorghum, Corn and Wheat Using Park's Method for Pooled Cross-Sectional and Time Series Data

Change in Yield	Constant	$\frac{PF_{t-1}}{PO_{t-1}}$	PF_{t-1}	PO_{t-1}	Sept. Weather	Har. Acres	Weighted Land	Irr. Acres	Change in Assets	Res.	O.S. Res.	D1	D1* O.S. Res.	"R^2"
Sorghum 23 states	-12.577 (1.52)		.009 (.666)	.418 (.113)	.099 (1.98)	.504 (1.48)		-.052 (.112)	-.016 (1.47)	.0089 (.151)	.0229 (.159)	-2.04 (1.92)		.23
Sorghum 23 states	-35.45 (5.37)	.081 (4.23)				.303 (.68)	-.084 (1.81)	.264 (.489)	.847 (.08)	.0037 (.731)	.152 (5.28)		.0066 (.587)	.21
Corn 39 states	-25.14 (3.82)	-.033 (1.35)			.211 (11.69)	-.476 (.20)		.586 (1.65)	.019 (6.19)	.0001 (.11)	.0014 (.71)	12.49 (1.40)	-.003 (1.01)	.21
Wheat 36 states	-15.49 (1.83)		-.020 (.82)	.368 (.763)	.078 (2.93)	.305 (1.06)		.251 (1.17)	-.0047 (.21)	-.0013 (.463)	.0044 (1.76)			.11

Numbers in parentheses are t values.

these states, possibly the result of irrigation and more intensive cultivation. However, this pattern was reversed in the sorghum and wheat models.

Although most of the hypothesized variables were significant at the 5% level of significance, there were some disappointments in these preliminary results, most notably in the research variables. The with-in state research variable was consistently significant in the wheat model. The outside research or "spill-in" variable as currently specified consistently had negative coefficients. An interaction term between the research budgets of the five top producing states of each commodity and the group of smallest producing states was tested but did not indicate a strong relationship of spillover in this direction. Further research effort will be directed towards other possible classification of states and areas as possible producers and consumers of research spillovers. Other specifications of the outside research variable will also be attempted.

Conclusions and Further Research

The results presented in this paper are very preliminary and are used at this point to illustrate the methodology. Further efforts need to be directed toward refining several of the explanatory variables such as weather and fertilizer. Since a primary feature of this study is an investigation of research spillovers, additional specifications of this variable need to be developed and tested. Other possible approaches are to incorporate within-region research expenditures of neighboring states and to utilize geoclimatic regions. An additional spillover topic is the issue of transferability of research results between similar commodities such as corn and sorghum and supporting research on it such as pest and weed control. Our future research plans are to investigate this type of spillover as well. Further refinements of these models will enable an assessment of individual lines of agricultural research and transferability of research activities.

Footnotes

1/See Kmenta, p. 508 for further development.

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Appendix A
Variables Used in Individual Crop Models

1. a) Yield--Yield per harvested acre. Values given in the U.S. Agricultural Statistics were used.
   b) Yield Change--The year to year change in the absolute level of yields per acre.
2. Price of Output--The national average price for each commodity. Available in Agricultural Prices.
3. a) Price of Fertilizer--Regional price values for N (anhydrous ammonia), P (Super Phosphate), and K (M of Potash) weighted by average amounts of N-P-K applied to each crop in each state. These fertilizer levels are listed in Fertilizer Situation and are based on surveys. Prices are available in Agricultural Prices.
   b) A regional Index Value of fertilizer and pesticide inputs was also used. Available in Changes in Farm Production and Efficiency, 1978.

4. a) Land--Harvested acres of each commodity. Available in Agricultural Statistics.
   b) Irrigated Acres--Irrigated farm acres by state. Available for census years from the 1969 and 1974 Census of Agriculture and interpolated for individual states between census years.
   c) Weighted Land--An average value per farm weighted by pasture, forest, irrigated, and non-irrigated cropland in each state. Values were developed by Davis for census years and interpolated for between census years.
5. Weather--Pasture and range conditions on June 1 and Sept. 1 by state. Index values are available in Agricultural Statistics, and are based on subjective evaluations by state crop reporting personnel.
6. Change in Assets--Year to year change in total machinery assets on farms for states. Available in Balance Sheet of the Farming Sector, 1979.
7. State Size Shifter--Slope dummies of states that are relatively small producers of each commodity. States with production between 1,000 and 100,000 acres are in this category. The Crop Reporting Board already excludes a number of states with smaller levels of production.
8. a) Research--Total expenditure on research ($1,000) for each commodity from Inventory of Agricultural Research FY 1967-1977. These values were lagged four and five years.
   b) Outside Research--Formulated as the total expenditure on research for a commodity by the top five national producers of that commodity. Also available from Inventory of Agricultural Research FY 1967-1977. These research expenditure values were deflated with a weighted index composed of average salaries of college and university teachers (AAUP Bulletin) and the implicit price deflator for government purchases of goods and services.