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RESOURCE PRODUCTIVITY IN DRYLAND FARMING*

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Several studies have used regression functions to study aggregates of industrial units[1] and farm units.[2] Limitations of time and space preclude a review of the considerable literature which has and is being developed. We report here the findings of such a study made of Montana dryland crop farms.

Procedure

The universe of farms studied is defined as non-irrigated farms in Montana Type of Farming Areas III and IV (northeast Montana: spring wheat) and VI and VII (north central Montana: mixed spring and winter wheat). A list of farms in these areas was furnished by the state office of the Production and Marketing Administration. It included all cooperators in the 1950 PMA program, who depended primarily on the sale of dryland crops for income: a total of 28,109 farms in all four areas. The PMA divides each Type of Farming area into "communities" (trade areas). These communities (159) were used in the sampling procedure to increase the efficiency of the sample. Twelve farmers (and six alternates) were selected in each of thirteen PMA communities. The communities were allocated among the areas proportionate to total farms in each area. Communities and farms within communities were then selected randomly. The 156 farmers sampled constituted 0.555 percent of the universe; 6.25 percent of farmers in the thirteen PMA communities.[3]

Information was obtained from farmers on conventional farm business survey records completed in personal interviews. The record was designed to gather data on volume of 1950 output and quantities of resources used to produce that output. Output was secured in both physical and value terms. State average prices were used to value wheat production. Farmer estimates were used for other products. Except for man-months of (used) labor and acres of land, data on resource quantities were obtained in value terms.

Two regression functions were fitted. In the first, the value of crop production, Yc, was expressed as a function of crop acres (X_{1c}), pasture acres (X_{2c}), man-months of labor used on crops (X_{3c}), expenditures made on capital equipment (X_{4c}), 1/ and expenditures on seed, fertilizer and spray (X_{5c}). In the second, the value of livestock production Y_s was expressed as a function of the value of feed fed (X_{1s}), man-months of labor used on livestock (X_{2s}), value of "livestock input" (X_{3s}), 2/ and expenditures on livestock facilities (X_{4s}). 3/

Results

Each function was linear in the logarithms of its respective variables. Theoretically, this shape of curve seems likely to represent in general the (competitive) relevant range of a total product function in respect to each of the independent

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1/ Machinery, buildings, and fences allocable to crops and custom hire.

2/ Non-breeding livestock at the beginning of the year plus purchases of non-breeding livestock during the year plus depreciation during the year of the breeding herd.

3/ Buildings and fences allocable to livestock plus expenditures for veterinary and livestock supplies.

variables (inputs). 4/ The use of this particular function represents an attempt to reflect diminishing marginal product with a minimal loss of degrees of freedom. Statistically, the fit was satisfactory: the adjusted coefficient of multiple determination was 0.7415 for the crop function and 0.9180 for the livestock function. Thus, about three-fourths of the variance in the value of crop production and about nine-tenths of the variance in the value of livestock production was statistically associated with co-variance in the selected independent variables.

As a result of transforming observed values in the variables into logarithms, the regression coefficient of each independent variable estimates the elasticity of output (in value terms) with respect to that variable. Thus the coefficient for cropland in the crop function reflects an estimate of the percent by which output would increase (or decrease, on the average) as cropland is increased (or decreased) by one percent.

"Marginal products" also can be calculated with the use of these coefficients by evaluating them at assigned values in the dependent and independent variables. Elasticities and marginal products for the crop and livestock functions are given in Table 1. The marginal product of a particular variable, Xi is obtained by multiplying its coefficient by the ratio Y/Xi. Values in Y and Xi are taken at their respective geometric means. For land and labor, the "marginal products" closely approximate the theoretical "values of marginal product": output is measured in value terms (1950 prices) and the inputs, in physical terms. Other independent variables, in value terms, yield "marginal products" which are interpreted in terms of "dollars worth" of additions or subtractions in the respective variables. 5/

Table 1. Derivatives from the Crop and Livestock Functions

Variable (Input)	Elasticity	t[a]	Marginal Product	Significant Differences: Elasticity[b]	Significant Differences: MP[c]
CROP FUNCTION[d]					
X_{1c}	0.224196	1.94	$ 4.68	5%	(f)
X_{2c}	-0.006735	0.37	-0.35	(f)	(f)
X_{3c}	0.065263	0.95	94.57	(f)	(f)
X_{4c}	0.338398	3.18	1.64	0.5%	(f)
X_{5c}	0.468972	4.59	8.31	0.5%	0.5%
LIVESTOCK FUNCTION[e]					
X_{1s}	0.287299	5.67	0.93	1%	(f)
X_{2s}	-0.017225	0.44	-16.06	(f)	0.5%
X_{3s}	0.582211	13.33	1.58	0.5%	0.5%
X_{4s}	0.104830	2.63	4.57	0.5%	0.5%

[a]These are "t-values" for the regression coefficients, shown above as elasticities.

[b]Probability that the elasticity does not differ from zero.

[c]Probability that the "marginal product" does not differ from the value of input: land (X_{1c} and X_{2c}) $3.50 per year; labor ($X_{3c}$ and X_{2c}), $200 per month; others, $1.00 per year.

[d]The value of Y_c at zero values for all included independent variables is 0.929689

[e]The value of Y_s at zero values for all included independent variables is 0.678881.

[f]Not significant at the 5% level of probability.

4/ I.e., that portion of the total product curve beyond the maximum in average product, possessing a diminishing rate of output increase with respect to increases in the input.

5/ The inclusion of "price" in the observations severely restricts the permanence of results. At best, they are good only for prices at 1950 levels and relationships.

Interpretation

From an economic viewpoint, data given in the second and fourth columns are probably the most interesting. The estimated "marginal products" may be used to measure deviations from optimum resource use. Theoretically, given unrestricted resource supply to the farmer and a purely competitive product market resources would be employed in quantities yielding a value of marginal product equal to the cost of a unit of the resource. For land, this cost would be the annual cost of maintaining an investment in one acre; for labor, it would be the cost of providing a month of (used) labor; for other variables, since the original observations were in dollar terms the values of their marginal product would (at optimum) equal $1.00.

The significance of differences between observed "marginal products" and optima were tested by indirect means. For each independent variable, a new elasticity was calculated on the basis of an "ideal" marginal product (equal to the theoretical optimum). Then the difference between the ideal marginal product and the observed was tested for significance by deriving a "test variable", u, given by

$$u = \frac{\text{observed elasticity - new elasticity}}{\text{standard error of observed elasticity}}$$

In the crop function, departures from the theoretical optimum occured only in expenditures on miscellaneous "crop supplies." Since crops were by all odds the major source of farm income, it may be concluded that the farmers sampled were, in 1950, doing an able job of determining the proportions of resources to employ. Nevertheless, it is also evident that they could extend the use of such materials as fertilizer and spray. So few instances of fertilizer use were found that this could hardly explain the results. Experimental evidence indicates that spray returns may reach these magnitudes.6/

Where livestock was found (111 farms) it accounted for about 25 percent of gross income. Forty-five farms had no livestock. Hence the more significant departures from optimum revealed in the livestock function might be expected. We note that only in feed, a major livestock production expense, was an optimum reached. Labor, statistically insignificant in its elasticity,7/ is found statistically different from optimum. This is a possible result for any variable which yields a negative coefficient (elasticity). It is evident that, on farms with livestock, it would pay farmers, on the average, to increase the size of their livestock enterprises at current feeding rates and to take better care of them through improved facilities.

Methodological Implications

An interesting discussion might be developed about questions raised which impinge on decision areas in both policy and farm management. Some implications, however, are fairly obvious from the results just presented. We propose here to examine briefly the function of this type of research in agricultural economic investigations.

An upper limit in the quality of any research study is fixed by the quality of observation which forms the basis for analysis. Data used in this study were gathered by means of a survey of randomly sampled farms. They are subject to all the elements of weakness (e.g., memory bias) and strength common to other survey data. Other studies, (notably Tintner's) have been based on farm records data. They, too, are subject to certain elements of weakness (lack of representativeness) and

6/ Unpublished material of D. C. Myrick and R. L. Warden, Bureau of Agricultural Economics, Montana State College, Bozeman, Montana.

7/ I. e., the coefficient shown could have arisen purely from chance.

strength (accuracy). These studies offer nothing new in the problem of securing data. Actually, information used in this study is completely adaptable to the traditional type of farm business analysis.

The basic goal of this type of study also differs little from that of other types of farm business analysis. All are designed to reveal points of organizational weakness and to discover alternatives which promise increases in net farm income. In this sense, all current analytical methods are complementary to budget methodology, wherein alternatives are tested synthetically for their effect on net farm income.

The difference arises from the treatment of data. In the traditional analysis, "efficiency factors" are derived and related, by relatively crude techniques of cross classification, to various "measures of success": income measures derived from net farm income. The result is a statement, usually in tabular form, suggesting certain factor values usable as "standards" to be striven for by farmers in an income group lower than the most successful. By these means, a considerable body of valuable data has been developed by farm management investigators.

Techniques used in the present study introduce a substantial refinement in the statistical analysis of data. In lieu of gross relationships suggested by "standards", the new method yields estimates of net regression coefficients--net to the extent that all relevant variables are included. Statistical measures are available, to be used with appropriate logic in determining adequacy in this respect.

Much remains to be done in refining the method. When variables are formulated in value terms, the usefulness of relationships is restricted to situations where price levels and relationships are the same as those which existed at the time of observation. More useful would be estimates of net physical input-output relationships. These would possess permanent usefulness, pending major changes in factor quality and/or production techniques. However, this limitation on the usefulness of results is not unique to the method employed in this study.

The variables employed in the present study actually represent aggregates of resources (except, possibly, for land and labor). Hence, the derived relationships apply only to aggregates. Yet the farmer controls individual resources: hours of tractor use, pounds of feed, etc. Here again, however, the weakness is not unique to this method. Moreover, it appears likely that this method is capable of considerable refinement.

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(1) For a reasonably complete bibliography, see the footnotes on pp. 51-57 in Gerhard Tintner, Econometrics (New York: John Wiley & Sons, Inc.) 1952, 370 p.

(2) Gerhard Tintner, "A Note on the Derivation of Production Functions from Farm Records," Econometrics, V. 12 (1944), pp. 26 ff; Gerhard Tintner and O. H. Brownlee, "Production Functions Derived from Farm Records," Journal of Farm Economics, V. 26 (1944), pp. 566 ff; Earl O. Heady, "Production Functions from a Random Sample of Farms," Journal of Farm Economics, V. 28 (1946), pp. 989 ff; Clifford G. Hildreth, A Study of Production Functions from Farm Record Data (unpublished Ph.D. thesis, Iowa State College, Ames, Iowa, 1947) and Hu Harries, "Development and Use of Production Functions for Firms in Agriculture," Scientific Agriculture, Agricultural Institute of Canada, V. 27, no. 10 (1947).

(3) For fuller discussion of sampling procedure, see Darrell F. Fienup, Resource Productivity on Montana Dryland Crop Farms, Montana Agricultural Experiment Station Mimeographed Circular 66, Bozeman, Montana, June, 1952, pp. 38-41.