245

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THE EFFECT OF TECHNICAL EFFICENCY ON OPTIMUM SIZE

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The Effect of Technical Efficiency on Optimum Size 1/

by

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I. Introduction

Farm and enterprise average cost curves are often interpreted as indicating that optimum size under "present technologies" is similar for most farms. However, wide farm-to-farm variations in size are observed and the causes of these size differences have not been well explained. Reasons often given for size variation include differences in goals, capital limitations, differences in risk preference, and institutional restrictions. These factors are hypothesized to cause some managers to operate at sizes different than the static optimum.

The purpose of this paper is to demonstrate that there may be an extremely wide range in the economic optimum size of farm or enterprise because of the wide technical-efficiency variation between farms. Technical efficiency is defined here as the ability to extract output from given resources. It may be the result of such factors as timeliness of milking, timeliness of feeding, methods of milking, etc.

The following example is based on a study of the dairy enterprise, 3/ however, other current Purdue studies of the hog 4/ and poultry enterprises 5/

1/ Journal Paper 1950, Purdue Agricultural Experiment Station, July 1962.

2/ Many helpful comments have been received from Emery Castle, G. Edward Schuh, Ludwig Eisgruber, and Joseph Havlicek.

3/ Arthur K. House, "Factors Affecting Cost of Milk Production in the Louisville Milkshed", unpublished M. S. thesis, Purdue University, June 1962.

4/ Ronald H. Bauman, Ludwig M. Eisgruber, Ralph E. Partenheimer, and Patrick P. Powlen, "Economies of Size and Economic Efficiency in the Hog Enterprise", Research Bulletin 699, Agricultural Experiment Station, Purdue University, 1961.

5/ Ludwig M. Eisgruber and Earl W. Kehrberg, "Effect of Flock Size on Egg Production Costs and Returns", Research Bulletin 688, Agricultural Experiment Station, Purdue University, December 1959.

indicate similar technical efficiency differences and cost curve shapes and, therefore, similar conclusions.

II. Analysis

An average cost function was estimated from the cross-sectional data of 195 dairy farms selected in a stratified random sample in the Louisville Milkshed. Resource quantity, resource combination, and level of technical efficiency were included as independent variables in a quadratic function explaining average cost per hundredweight of milk production: 6/

$Y = f\ (X_1, X_2, X_3, X_4, X_5, X_6)$ Y = average cost per hundredweight of milk

X_1 = technical efficiency index

X_2 = number of cows

X_3 = building investment

X_4 = labor hours

X_5 = forage - tons

X_6 = grain - TDN

The technical efficiency variable was constructed from the residuals of a Cobb-Douglas production function which included the above variables X_2 through X_6. 7/ After the production function was estimated, the observed resources of each farm were entered in the function and a predicted output was calculated. The predicted output was divided by actual output (from marketing records) and multiplied by 100 to obtain the technical efficiency index. Thus, the index reflects the percentage that actual output is of predicted output.

While this procedure of estimating technical efficiency may be criticized because input measurement error and regression fit may bias the index and while

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6/ See Table 1 for regression coefficients, standard errors, and coefficient of determination.

7/ See Table 2 for regression coefficients, standard errors, and coefficient of determination of the Cobb-Douglas production function.

a more independent measure may be more desirable, it is probably closely associated with technical efficiency. Information was not available for many technical practices; however, the index was significantly related to the number of years cows are kept in the herd and the percentage of cows artificially bred.

A Bartlett's test indicated homogeneity of variance of the technical efficiency index at all levels of herd size, thus indicating uniform percentage variance and increasing absolute deviation as resource employment and output increased. Size magnified the absolute effect of technical efficiency on output.

In light of the homogeneity of variance of the index at all levels of resource employment, long-run average and marginal cost functions were estimated with index levels of 100 and 130 while least-cost resource combinations were approximated as the level of output was increased (Figure 1).

The two cost functions are similarly shaped; but the higher the level of technical efficiency, the larger the level of output and herd size at the minimum cost point and the more slowly average and marginal costs rise as size increases beyond the minimum cost point.

The wide differences between the levels of cost functions with varying technical efficiency and differences in rates at which these cost functions rise result in substantial differences in optimum herd size with 1957 price. The optimum herd size ranges from 40 cows for managers with an index of about 100 to about 90 cows for managers with an index of 130, assuming the high level of efficiency could be maintained as output is increased. Although there are economies of size to the 30-40 cows range for all levels of technical efficiency, it is possible for a firm with high technical efficiency to survive with any herd size between 10 and approximately 90 cows. To maximize profit, however, this firm would expand to near the 90-cow level or to the level of resource employment where technical efficiency for this particular manager begins to decline substantially. On the other hand, the manager with average to slightly below average technical efficiency would be forced into the 20-60 cow range.

III. Summary and Implications

Continuous rapid change in agricultural technology over a long period of time along with differences in the human resource have resulted in a wide variation in technical efficiency among farms. The most technically efficient farms are likely to have an average cost of production considerably below price. In many enterprises, the average and marginal cost functions rise slowly as size is increased beyond the minimum cost point; this seems to be especially true for farms with high technical efficiency. In addition, the low point on the long-run average cost curve may be at larger sizes for farms with greater technical efficiency.

Therefore, cost functions estimated without specifying the level of technical efficiency may fail to portray the true slope of a function for any level of technical efficiency and would probably not show the true slope of average cost curves for managers with other than average technical efficiency. Since the wide range in technical efficiency causes price to be considerably higher than the low point of the long-run average cost curve of the technically efficient farm, this farm's optimum size would be beyond the low point of the average cost function. Thus, cost functions estimated without measures of technical efficiency will have only limited usefulness for managers making size decisions. Differences in technical efficiency may be a major factor explaining why farms of a given type in a given geographic area vary widely in size.

Technical efficiency also affects the substitution rate between resources and must be accounted for if optimum resource combination is to be determined.

For example, the results of this study indicate that managers with high technical efficiency could minimize cost by feeding large amounts of concentrates relative to forage while managers with low technical efficiency could minimize cost by feeding large quantities of forage and small amounts of concentrate.

Measures of technical efficiency can greatly increase the usefulness of average cost functions for policy decisions. With the addition of this relevant variable, better estimates can be made of the effect of various farm programs on supply and economic efficiency. Also, the differences in cost function shape from low to high technical efficiency can be the basis for predicting future adjustments in size.

If the more important components of technical efficiency can be identified and their effects quantified, this could serve as a basis for an educational program which might increase the average level of technical efficiency. Thus, certain products could be provided to society with the use of less resources and therefore at a much lower cost. 8/ For example, the average revenue per 100 pounds of milk was $4.60 in the Louisville milkshed in 1957. If the technical efficiency of all producers could be improved to the level shown by AC and MC 130, a marginal revenue of about $2.90 would probably be sufficient to obtain the amount of milk supplied in 1957.

With expectation of continued rapid change in agriculture, wide variations in technical efficiency are likely to continue. Measures of technical efficiency would be of benefit to managers for making more accurate decisions with respect to size and resource combination. These measures could be of benefit to policy makers by providing a better basis for predicting the effects of alternative

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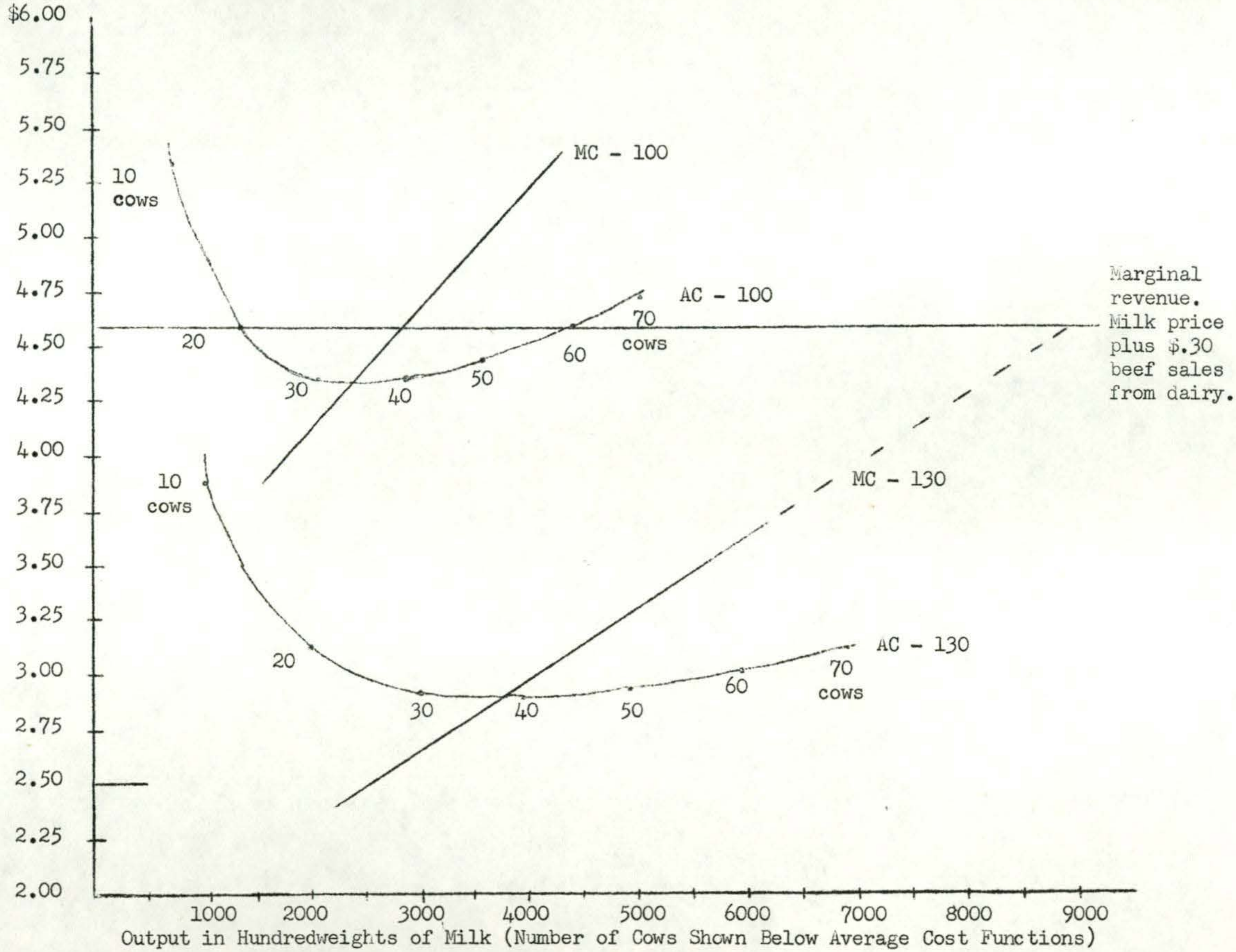
8/ Increasing the level of technical efficiency may involve certain costs not accounted for in the cost function estimated in this study. These costs should be considered when changing the level of technical efficiency.

Figure 1. Optimum Output and Herd Size When the Technical Efficiency Index is 100 and 130



programs. If accompanied by educational programs, measures of causes of technical efficiency differences can be used to improve resource use. It would seem, therefore, that more effort should be directed toward measuring technical efficiency differences and causes of these differences.

Table 1. Statistical Values Relating to a Cost Function for Grade A Milk in the Louisville Milkshed, 1957 1/

REGRESSION COEFFICIENTS			
	Variables 2/	Estimated Values	Standard Errors
a		3.3264	---
X_1	Technical efficiency index	- .0237	.0074
X_2	Number of cows	.0425	.0193
X_3	$\frac{1}{X_2}$	22.4421	6.8357
X_4	Building investment per cow	.0027	.0011
X_5	$X_2 \cdot X_4$	- .00003	.00004
X_6	Hours labor per cow	.0067	.0016
X_7	$X_6 \cdot X_2$	- .00003	.00006
X_8	Tons forage per cow 3/	.0473	.1371
X_9	$\frac{1}{X_8}$	1.0160	.4413
X_{10}	$X_1 \cdot X_8$	.0009	.0008
X_{11}	TDN grain per cow	.0006	.0002
X_{12}	$X_1 \cdot X_{11}$	-.000006	.000002
X_{13}	$X_{11} \cdot X_8$	-.000009	.000028
X_{14}	$X_1 \cdot X_2$	- .00014	.00016
X_{15}	Per cent heifers are of cows 4/	.0081	.0037

$R^2 = .7322$ $\qquad$ $n = 195$

1/ Equation - Y(cost per hundredweight) = $a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_9 X_9 + b_{10} X_{10} + b_{11} X_{11} + b_{12} X_{12} + b_{13} X_{13} + b_{14} X_{14} + b_{15} X_{15}$

2/ For further explanation of variable selection see Arthur K. House, "Factors Affecting the Cost of Milk Production in the Louisville Milkshed", unpublished M. S. thesis, Purdue University, June 1962.

3/ Excluding Pasture.

4/ Included to account for differences in dairy beef production.

Table 2. Statistical Values Relating to a Production Function for Grade A Milk in the Louisville Milkshed, 1957 1/

REGRESSION COEFFICIENTS			
Variables		Estimated Values	Standard Errors
a		1.3213	---
X_1	Building investment	.0174	.0370
X_2	Tons of forage 2/	.1379	.1102
X_3	TDN from grain	.1061	.0937
X_4	Hours of labor	.0203	.0725
X_5	Number of cows	.7398	.1681

$R^2 = .781$ n = 195

1/ Estimated Equation - Y(hundredweight milk produced) = $aX_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5}$.

2/ Excluding pasture.