

RESEARCH IN THE ECONOMICS OF THE AGRICULTURAL FIRM

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Research in this area is, in principle, designed primarily to aid farmers in making decisions. At state colleges in the United States this pragmatic orientation derives, at least in part, from the administrative structure which connects the teaching, research and farm advisory activities found in each of the states. As in other endeavors agricultural economists have become quite specialized in their interests, e.g., marketing, land-tenure, governmental policy, price analysis, etc. The discussion which follows falls into the specialization that has traditionally been called farm management. Even though the primary research objective in this specialty may be that of helping individual farmers with their economic problems, studies of this type are also frequently of aid in analysis of national agricultural policy.

The examples and discussion which follow represent a further specialization within the field of farm management; reference is made only to types of analysis which utilize rather directly certain aspects of the theory of the firm under conditions of certainty.¹ Thus, for our purpose here, the static theory of the firm is viewed as a sufficiently close approximation of the decision process employed by farmers to be useful as basis for empirical work. This is a somewhat controversial point among agricultural economists. On the one hand, some farm management research workers are devoting considerable effort to a study of the decision process itself, drawing concepts not only from economics, but from other disciplines as well.² On the other hand, traditional accounting concepts continue to play an important role in much of the primarily descriptive empirical research work in farm management.

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1. For a discussion of the use of uncertainty models in agriculture see Hildreth, C. Problems of uncertainty in farm planning. *Journal of Farm Economics*. 39:1430-1441. December 1957.
2. See a group of papers: Progress and problems in decision making. *Journal of Farm Economics* 37:1097-1125. December 1955 and Johnson, Glenn L. Methodology for studying decision making. *Journal of Farm Economics* 39:1215-1226. December 1957.

Production Function Analysis

The familiar concept of the production function has served as a basis for a number of economic studies since World War II.¹ In general, these studies have been at two levels – (1) the total farm firm and (2) technical sub-units within the firm.

The total farm production function studies have characteristically used data from a sample of farms and have employed a single function linear in the logarithms of the variables (Cobb-Douglas) with five or six classes of inputs.² The total product or dependent variable has usually been some type of aggregate sales figure. Studies at this level serve chiefly to aid in making a general productivity analysis when, for example, interest lies in comparison of estimated marginal value productivities between areas, time periods, institutional arrangements, etc., or a comparison of estimated marginal value productivities with market resource prices to detect deviations from equilibrium.

The popularity of total farm production function analysis has waned considerably in the United States in recent years. This is due to a more general recognition of problems of interpretation which affect the use of the results either in giving advice to farmers or as a guide to questions of governmental policy. Questions of interpretation center around the degree and kind of aggregation into the value of product and input categories, the omission of "management" as a variable, and the frequent high intercorrelation among input categories.³

Use of total farm production function analysis may however, serve as a valuable supplement to the usual type of descriptive studies made of the economic aspects of agriculture. Much effort is devoted by agricultural economists to the description of changes in the structure of agriculture through time. Trends in the "land-labor ratio", "labor-capital ratio", etc. as well as trends in the percentage composition of total costs (land, labor, machinery, etc.) have been described in some detail in the literature in agricultural economics. Use of the logic of marginal productivity analysis aids in a more systematic exploration of the implications of such data.

1. See Kristensen, Erik. Produktionsfunktioner. Ugeskrift for Landmænd 38: 547-550 and 39:567-569 1956, and also Kristensen's article: Production and Production Functions in Agriculture. Royal Veterinary and Agricultural College Yearbook 1958. pp. 26-47. Copenhagen 1958.
2. For an example of an attempt to employ simultaneous equations see French, B.L. Estimation by simultaneous equations of resource productivities from time series and cross sectional farm observations. Unpublished Ph.D. thesis. Iowa State College. 1952.
3. Griliches, Zvi. Specification bias in estimates of production functions. Journal of Farm Economics 39: 8-20. February 1957. Plaxico, James S. Problems of factor-product aggregation in Cobb-Douglas value productivity analysis. Journal of Farm Economics 37: 664-675. November 1955.

A recent study is a modest attempt to supplement such description by the use of the concept of the production function.¹ The study is based on data from 146 North-Central Illinois farms that had kept accounting records during the period 1936-1953. Examination of the data indicated, among other things, that the average size of farm increased during this period. The question arises (and the agricultural economist can hardly avoid attempting an answer) whether farm size has increased rapidly enough, too rapidly or at a satisfactory rate during this period. Questions concerning the level of use of other broad resource categories are also frequently of interest for both public and private policy. The estimated elasticities of production for each input category are presented in Table 1. A one-percent increase in, e.g. land investment in 1936-1939 would have resulted in an estimated increase in value of product of 0.292 percent.

Table 1. Elasticities of Production: 146 North-Central Illinois Farms.
1936-39 and 1950-53

Years	Land Investment	Buildings and Soil Improvements	<i>Input</i>			
			Livestock Investment	Labor	Power and Machinery	Purchased Feed
1936-39	.292 (.042) ^a	.133 (.025)	.027 (.022)	.511 (.054)	.024 (.021)	.086 (.012)
1950-53	.410 (.036)	.032 (.017)	-.010 (.016)	.304 (.040)	.137 (.038)	.166 (.012)

a) Standard errors of regression coefficients are in parantheses under their respective coefficients.

Clearly, some criterion is needed to assess the desirability of the changes in resource use. Marginal value productivities might be calculated using the sample mean values for the value of product and each of the input categories. Thus the estimated marginal value productivity of land investment in 1936-39 would be $0.292 (\bar{y}/\bar{x}_1)$, where \bar{y} and \bar{x}_1 represent the mean values of value of product and land investment respectively. Estimated marginal value productivities of each input might be computed in this fashion and compared with their unit market costs to determine the proximity to an equilibrium in terms of the marginal value productivity of each input equalling its marginal factor cost. However, at least two problems complicate this type of an interpretation. First, since production is not riskless, each estimated marginal value productivity contains a risk premium, the size of which it is difficult

1. Swanson, Earl R. Resource adjustments on 146 commercial Corn-Belt farms. *Journal of Farm Economics* 39: 502-505. May 1957.

to evaluate. Further, some input categories, for example livestock investment and power and machinery, contain a mixture of assets of varying lengths of life. This makes a meaningful estimate of a market cost for these inputs quite difficult. Ideally, the accounting procedures should permit a classification of inputs more appropriate for productivity analysis. However, most farm accounting procedures are designed for a different type of analysis.

Rather than using the marginal value product equals marginal factor cost type of equilibrium as a norm, it was believed in this study to be more meaningful to assume that the pre-World War II years 1936-39 represented a reasonably good degree of resource adjustment. Rapid changes in farm size and agricultural technique occurred both during the war and in the postwar years. We then pose the question: Were there significant departures in 1950-53 from the "equilibrium" of 1936-39? This formulation does not completely avoid the problems of the risk premium being included in the estimates of marginal value productivity and the aggregation of assets of unequal lengths of life, but this comparison appears to be more plausible than one involving marginal value productivities and market factor costs.

The input elasticities necessary in 1950-53 to equate marginal value productivities between 1936-39 and 1950-53 are as follows:

Land Investment	Buildings and Soil Improvements	Livestock Investment	Labor	Power and Machinery	Purchased feed
.254	.081	.030	.515	.045	.146

When these are compared with the actual estimated values for 1950-53 (Table 1), statistically significant differences occur (1% level) for land and labor. Since, in order to equate the 1950-53 marginal value productivity of land to its 1936-39 level, a lower elasticity is needed in 1950-53 than that which actually obtained, the pressure for larger farms is indicated. The opposite is true for labor; a higher elasticity is needed in 1950-53 to restore 1936-39 "equilibrium". If the 1936-39 period is accepted as one of reasonably good adjustment, the intervening years have apparently disturbed land and labor adjustments on these farms to a greater degree than in the case of the other resources. Measured against the base period 1936-39, quantities of the other input categories have apparently been adjusted in a satisfactory fashion to the changing environment.

Technical unit production function studies are involved with only a part of the total farm business. Consequently there is, in general, less aggregation of both inputs and products. Clearly the implication of these studies is to provide data rather immediately useful to the farmer in making decisions. Responses of crop yield to irrigation water, fertilizer etc. are examples of

technical unit production functions. The analysis is usually based on experimental data and the most successful studies have involved the cooperation of the technical specialist (agronomist, engineer, animal scientist, etc.), the economist, and the statistician.

It is useful to separate the two aspects of this type of study – the estimation of the technical relationship and the optimization procedure. If a continuous function is fitted to the data, the usual maximization of a profit equation subject to the production function may be the optimizing procedure. However, the technical coefficients from continuous functions may also be used in conventional planning and linear programming (see below). On the other hand many experiments are conducted with essentially continuous variables but the statistical analysis does not include the fitting of a continuous function. If, for example, a fertilizer experiment is conducted with various levels of fertilizer and several replicates at each level, an analysis of variance might be performed to determine if significant differences exist among levels. Such results may be used in conventional planning and linear programming but do not permit the refinement of being able to find optimum input combinations and level of production by methods of calculus.

Among other difficulties facing the continuous function analyst is the choice of the mathematical form of the function for which the parameters are estimated. Although it may seem that the relevant physical and biological theory would dictate the form, such is not usually the case. Unfortunately, the economic implications sometimes vary considerably with what is, within rather wide limits, largely an arbitrary choice of the functional form.¹

As an example of a technical unit production function, consider the following Danish study on swine feeding.² In this study a function linear in the logarithms of the variables was employed as well as a quadratic function. The quadratic function was chosen as a more realistic representation of the production surface. The estimated function was:

$$Y = -113.2 + 0.7630 X_1 - 0.001995 X_1^2 + 0.4994 X_2 \\ - 0.0002469 X_2^2 + 0.0002087 X_1 X_2$$

where Y = kg. of dressed pork, X_1 = feed units in a protein mixture, and X_2 = feed units of barley. Using various price relationships it was possible

1. Johnson, Paul R. Alternative functions for analyzing a fertilizer-yield relationship. *Journal of Farm Economics* 35: 519-529. November 1953, Baum, E.L. et.al. *Methodological Procedures in the Analysis of Fertilizer Use Data*. Iowa State College Press. Ames, Iowa. 1956. 218 pp.
2. Vestergaard Jensen, E. Forskellige protein- og fodernormer til svin i driftsøkonomisk belysning. *Tolvmandsbladet* 30: 8-16. January 1958.

to compute optimum combinations of protein feed and barley as well as the optimum feeding intensity.

In order for an optimum derived for a technical unit itself to be useful, one must be able to view this technical unit more or less independently of the other aspects of the firm. If such is not the case, in order to plan the operations of the total farm, an analysis is needed which takes into account the inter-relationships among the various technical units. The total farm production function discussed above is seldom suitable for such planning; in general, the level of aggregation in the variables is such that they are too gross to have operational meaning. Total farm production function analysis may play an important preliminary role in selecting alternatives in planning, but it must be followed by a type of planning procedure in which it is possible to specify in greater detail the kinds and quantities of products and inputs for an optimum organization.¹

Farm Planning Procedures

Conventional planning methods usually start with consideration of the "best" use of a single resource. In some agricultural areas the focus is on land use, in others, labor or capital use. For example, if the procedure is land use oriented, the crops to be grown are selected in the initial phases. Then livestock is added to use resources not fully utilized by the cropping system. However, the interrelations between the cropping system and the livestock system may be such that it is necessary to modify the previously selected cropping system in order to include what is believed to be a desirable livestock system. In short, conventional planning proceeds piecemeal by considering in sequence each part the farm business; simultaneous consideration of the specified available resources and alternative products is not possible.

Cost-of-production studies are frequently used as a basis for planning in the conventional fashion. Thus, the product which shows the most profit receives the greatest emphasis in the planning procedure. Other information, however, must be informally injected into the plan. The difficulty in being able to draw logical conclusions from cost-of-production studies is the failure of the technique to adequately account for opportunity costs. In the central U.S., market prices for some of the resources (especially labor during slack seasons and the intermediate product of hay and pasture) are not applicable in terms of decision making.

Although conventional planning methods or "budgeting" lack mathematical rigor, they can be sufficiently systematic to be quite useful. These

1. Swanson, Earl R. Determining optimum size of business from production functions. Chapter 15 in *Resource Productivity, Returns to Scale, and Farm Size*, ed. by Heady, et.al. Iowa State College Press. Ames. Iowa. 1956. 208 pp.

methods form an important part of the undergraduate instruction in the agricultural colleges in the United States. The farm advisory service also employs various forms of budgeting in their activities. Indeed, one of the needed improvements in the farm advisory service is to emphasize the importance of viewing the farm business as a totality. Conventional planning methods aid in developing this viewpoint.

Linear programming has certain advantages over conventional planning. Using the linear programming model for purposes of short-run resource allocation, the opportunity costing procedure can be built into the model and we may avoid the explicit pricing of resources or intermediate products for which the market price fails to give a satisfactory indication of the on-farm price. In this manner, the linear programming model may offer a better guide to planning than conventional cost accounting procedures in which more or less arbitrary cost allocations among products are performed.

The logic and computational aspects of linear programming have previously been presented in this journal.¹ In developing a farm planning model for linear programming, we usually start with a specification of the relevant restricting resources. Thus we specify the quantities (and seasonal distribution) of the labor supply, land, building, capital, etc. Next we select the alternative products (activities) to be considered and assemble data on the resource requirements for each product. The data may, and usually do, come from a variety of sources. Some coefficients may come from selecting a few points on continuous functions that have been fitted to experimental data. Data on labor requirements is most likely to come from special studies conducted on farms. Certain technical data may come from farm accounts or surveys. Some coefficients may be simply the judgment of a technical expert. This variety of sources of technical data makes it quite difficult in practice to statistically assess the confidence limits of the solution of a programming problem. The same could, of course, be said concerning conventional planning results.

After the technical data have been assembled, other activities are added to the programming model to provide for the flow of intermediate products from a primary to a secondary enterprise, e.g., hay fed to livestock. In addition, we add buying and selling activities to permit the direct sale of primary products, e.g., grain, as well as their purchase in the event the supply produced proves inadequate for the requirements of the secondary enterprises, e.g., livestock. Finally, we choose prices and construct the profit equation, which is maximized subject to the specified restraints. The data requirements for programming are very similar to those in conventional

1. Danø, Sven. Linear programming i produktionsteorien I, II og III, *Nationaløkonomisk Tidsskrift* 93:94-117, 205-233. 1955, 94:47-61. 1956.

planning and, of course, programming does not improve the basic technical data or price assumptions, but it does aid in a more systematic study of their implications.

Rather than give the details of a specific model, part of the results of one study are presented in Figures 1 and 2.¹

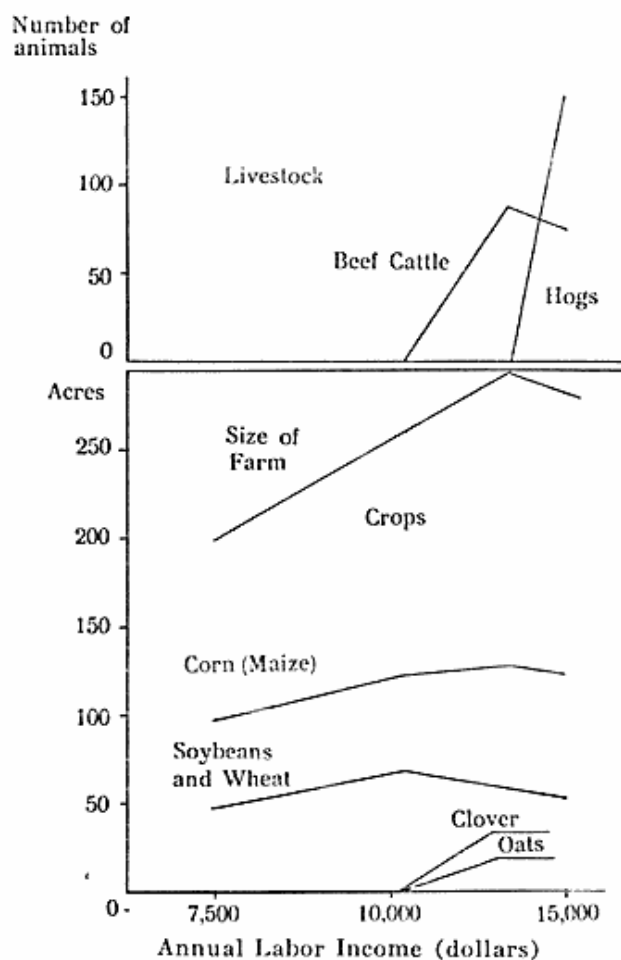


Figure 1. Minimum labor farming systems for various labor incomes. Labor use ranges from approximately six months to a maximum of twelve months. Systems refer to highly productive soils in central Illinois. Prices are 1946-1955 averages

In Figure 1 various crop and livestock combinations are presented which minimize labor input for various levels of annual labor income.² In effect,

1. Swanson, Earl R. Highest return farming systems for Drummer-Flanagan soils. Illinois Agr. Exp. Sta. Bulletin 629. June 1958. For an example under Danish conditions see Swanson, Earl R. A linear programming analysis of a family farm in Zealand. *Erhvervsøkonomisk Tidsskrift* 23:1-14. 1959.
2. Candler, Wilfred. A modified simplex solution for linear programming with variable capital restrictions. *Journal of Farm Economics*. 38: 940-955. November 1956.

the figure shows a shift from systems of farming in which grain is produced for direct sale to systems of livestock farming as labor inputs increase.

The effect of price changes on optimum farming systems may also be studied by the linear programming technique.¹ In Figure 2 the boundary line, for example, between areas A and B indicates price combinations of corn and hogs in which farming systems A and B yield the same labor income.

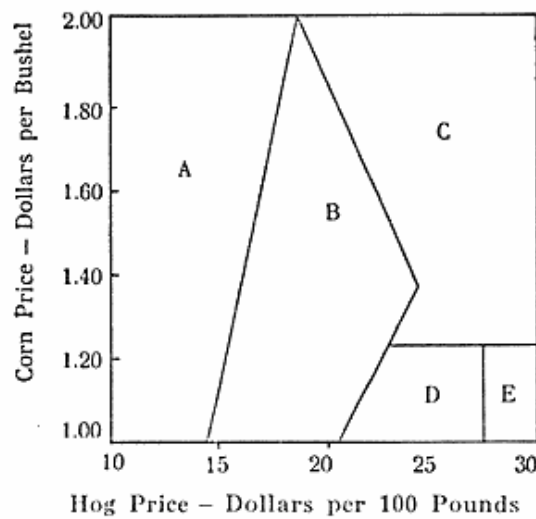


Figure 2. Price map for 160-acre farm with one-man labor supply. The letters indicate the farming systems that give maximum labor income with corn and hogs at the prices indicated on the vertical and horizontal scales

Area on price map	Farming Systems						
	Land use					Livestock	
	Corn	Soybeans	Oats	Wheat	Clover	Hogs	Beef Cattle
	(acres)					(litters)	(number)
A	72	23	14	23	28	—	144
B	12	21	15	21	31	53	105
C	76	30	8	30	16	77	—
D	57	29	15	29	30	56	93
E	56	40	8	40	16	77	—

Linear programming offers promise in developing more reliable guides to farm planning through the development of "standard" or "bench-mark" farms within an area. An individual planning service for farmers does not, at the present time, appear to a reasonable undertaking for farm advisory

1. Hildreth, C. Economic implications of some cotton fertilizer experiments. *Econometrica* 23: 88-98. 1955.

services in the U.S. Linear programming also offers a method of testing "rules of thumb", by determining the range of situations over which the rules may be applicable. As is true in the development of "standard" farms, an important problem in establishing the generality of the rules is the selection of modal resource supplies and production coefficients.

One of the important values of the linear programming technique is the rigor which it enforces in thinking about the farm business. In a sense, it transfers the judgment and intuition involved in developing and comparing alternative plans to the establishment of a set of realistic relationships. Another important consequence of farm planning by linear programming is the dramatic way in which we discover deficiencies in our knowledge of technical coefficients. This may serve as a guide to technical workers for needed research.

It is not surprising that we find some actual farms that are quite successful following systems developed by trial-and-error that closely approximate optimum solutions as developed by linear programming methods. It might be argued that the research worker and his counterpart in the advisory service should simply study successful farms, describe their practices, and use this as a basis for giving recommendations to other farmers. However, linear programming, as well as classical production theory, gives us a conceptual framework which permits us to better explain and understand empirical phenomena. Such understanding is a prerequisite to being able to predict and hence aid farmers in decision making.