MARGINAL PRODUCTIVITIES OF INVESTMENTS AND EXPENDITURES, SELECTED INGHAM COUNTY FARMS, 1952

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Robert Vance Wagley

1953

This is to certify that the

thesis entitled

"Marginal Productivities of Investments and Expenditures, Selected Ingham County Farms, 1952"

presented by

Robert Vance Wagley

has been accepted towards fulfillment of the requirements for

Master of Science degree in Agricultural Economics

Glenn L. Johnson
Major professor

Date October 30, 1953

O-169

MARGINAL PRODUCTIVITIES OF INVESTMENTS AND

EXPENDITURES, SELECTED INGHAM COUNTY FARMS, 1952

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of
Agricultural Economics

by

Robert Vance Wagley

1953

Approved by Glenn L. Johnson

Robert Vance Wagley

ABSTRACT

Marginal Productivities of Investments and Expenditures, Selected Ingham County Farms, 1952

The purpose of this study was to construct estimates of marginal value productivities for groups of inputs used in the operation of farm businesses. It was anticipated that these estimates would be valuable to farm managers, agricultural extension workers, representatives of lending institutions and research workers in judging the efficiency of farm business organizations and planning any needed reorganization.

A Cobb-Douglas type production function was used in deriving the estimates. This is an exponential equation, linear in logarithmic form and in that form is expressed as $\log X_1 = \log a + b_2 \log X_2 + b_3 \log X_3 + - - - - - - + b_n \log X_n$, where X_1 (gross income) is the dependent variable, $X_2 - - - - - X_n$ are groups in independent variable inputs and the b_i's are elasticities of $X_2 - - - - - X_n$ with respect to gross income. The equation was fitted by the least squares regression technique to find the b_i's. The marginal value products for each independent input category were then computed by the general formula: $MVP_{X_i} = \frac{b_i\,(EX_1)}{X_i}$

Where (EX_1) is the expected gross income of the set of X_i's under consideration and X_i is the antilog of $\log X_i$ in the estimating equation.

Robert Vance Wagley

Data were taken from a purposive sample of thirty-three Ingham County farms located mainly on Miami, Hillsdale and Conover soils for the year 1952. In purposive sampling, farms are selected so as to include imperfectly adjusted farms to reduce intercorrelation among the inputs and to secure sufficient range in the data to assure reliable estimates of the regression coefficients and hence the marginal value productivities. The data were summarized and grouped into categories having a meaningful relation with gross income.

The input categories, their geometric mean quantities, the regression coefficients and marginal value products were:

Input Category	Geometric Mean Quantity (Usual Organization)	Regression Coefficients	Marginal Value Products
X_2, land	130 acres	.211072	$ 16.56
X_3, labor	14 months	.041663	30.19
X_4, expenses	$3 348	.250010	.76
X_5, livestock-forage investment	7,126	.448209	.64
X_6, machinery investment	6,803	.125561	.19

The gross income computed for the usual organization was 10,202 dollars.

Tentative conclusions as regards the usual organization of farms in Ingham County in 1952 were that too much labor and expenses were being used relative to the other input categories. Machinery investments were believed to be in about the proper proportion relative to other groups of inputs. Land and livestock-forage categories were earning high returns and the desirability of expanding their use per farm was indicated. This was particularly true of livestock and forage investments. Livestock and forage investments can be increased by expanding quality as well as quantity. In fact, other research indicates the advisability of expanding quality before quantity. Increased use of inputs earning high rates of return would tend to reduce their marginal value products and increase the marginal value products of other input categories earning low rates of returns. This, in turn, would result in a better combination of productive resources and higher net farm incomes under 1952 price and weather conditions.

MARGINAL PRODUCTIVITIES OF INVESTMENTS AND EXPENDITURES, SELECTED INGHAM COUNTY FARMS, 1952

A Thesis

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of
Agricultural Economics

by

Robert Vance Wagley

1953

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the many people who assisted in the development and completion of this piece of work. The author is particularly indebted to Dr. Glenn L. Johnson for his guidance and constructive criticism in the preparation of this thesis.

The many helpful suggestions given by members of the Department of Agricultural Economics are deeply appreciated. Dr. H. L. Brown, Dr. L. L. Boger, Dr. H. E. Larzelere and Mr. H. S. Wilt were especially helpful.

The author wishes to thank the farmers interviewed whose splendid cooperation made this study possible.

Thanks are also due for the assistance given by Mrs. Arlene Nelson and Mrs. Phyllis Quinn of the secretarial staff of the Department of Agricultural Economics for typing the original manuscript and for the assistance given by Mrs. Edna Kenworthy for the final typing of the manuscript.

Finally, the author is indebted to his wife, Virginia, for her assistance in the preparation of material and for her sincere encouragement at all times.

The author assumes full responsibility for any errors which may still be present in this manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

This study was conducted with two broad objectives in view. The first objective was to add something to the empirical frame of reference within which judgement must be exercised relative to problems of farm management. Secondly, it was hoped that the success of further research of a similar nature might be enhanced as a result of the experience accumulated in this study.

This study is addressed to the problem of efficient resource use in securing farm income. The major problem often is not one of deciding what inputs will be used in production but rather the quantities and proportions of numerous inputs most likely to maximize net returns.

Farm managers, credit men, extension workers and teachers of vocational agriculture are repeatedly faced with the question, "Will it pay?" Usually this question is posed with reference to a proposed expansion or reorganization of some phase of the farm business. In other words, an estimate is sought of the ratio between additional returns which may be expected and the additional cost which will be incurred by changing the quantity used of one or more productive inputs. Although the question is not usually stated in the language of the economist, the concepts of the marginal value product[1] and the marginal factor

---

[1] Increment in total value product (gross income) resulting from using an additional unit of input.

cost[2] are clearly implied. The same kind of logic is used in comparing the probable effects of increasing the use of one input or group of inputs against the increased use of one or more alternative inputs. The logical choice when faced with such problems is to increase the use of those resources expected to yield the greatest return per additional dollar of cost incurred by their use.

The theoretical concepts upon which such decisions are based are discussed and related to farm businesses in Chapter II.

In order to add to the empirical frame of reference available to farm management men, estimates of the effect on gross farm income of the last unit of an input or group of inputs used in the productive process will be constructed. An estimating equation, commonly referred to as a Cobb-Douglas type production function will be employed in arriving at the estimates. The Cobb-Douglas function will be discussed in Chapter III and the problems of applying this function to the analysis of farm business data will be taken up. Chapter III will also review experience accumulated in previous studies of a similar nature.

A description of the sample used in this study and methodology employed in measuring productive inputs will be presented in Chapter IV.

Chapter V will deal with (1) the fitting of the function to the data gathered; (2) the evaluation of statistical results; and (3) the possibilities of reorganizing farm businesses on the basis of these statistical results.

---

[2] Increment in total cost resulting from using another unit on input.

The general conclusions derivable from the study will be presented in Chapter VI.

CHAPTER II

THE THEORETICAL BACKGROUND

Use of the marginality concepts in the theory of the firm assumes that firms attempt to maximize something. That "something" is usually assumed to be profits. Managers of firms seek an allocation of the productive resources over which they exercise control which will maximize profits. Determination of the optimum allocation of productive resources which will maximize profits is the objective of marginal analysis.

One necessary step in finding this optimum is determination of the change in total product brought about by the last unit used of a productive resource. Using the standard of dollar value, the change determined is the change in the value of the total product. This change is the marginal value product (MVP) of the last unit of a productive factor used.[1]

Marginal value products comprise one part of the ratio by which high profit points are determined. The other part of this ratio is marginal factor cost, which is composed of all of the costs involved in using the last unit of input and is the minimum expected return.

---

[1] George J. Stigler, The Theory of Price (New York: The Macmillan Company, 1947), p. 244.

Optimum Resource Utilization

It is by comparison of marginal value products and marginal factor costs that the optimum quantity of an input (X_1) to use in the production of a product (Y) may be found. The relationship of marginal factor cost ($MFC_{X_1}(Y)$) to marginal value product ($MVP_{X_1}(Y)$) defining this optimum is:[2]

$$(1) \quad MVP_{X_1}(Y) = MFC_{X_1}(Y) \text{ or } \frac{MVP_{X_1}(Y)}{MFC_{X_1}(Y)} = 1$$

While this is a useful theoretical concept, the productive process of the firm involves two or more inputs in producing a given product. There is an optimum combination of these inputs which may be used in the production of a given product (Y). This optimum combination is reached by a firm or an enterprise when the ratios existing between marginal factor cost (MFC) and marginal value product (MVP) are the same for each variable factor used by the firm. This ratio may be expressed as:[3]

$$(2) \quad \frac{MVP_{X_1}(Y)}{MFC_{X_1}(Y)} = \frac{MVP_{X_2}(Y)}{MFC_{X_2}(Y)} = \text{------} = \frac{MVP_{X_n}(Y)}{MFC_{X_n}(Y)}$$

where X_1, X_2, ----- X_n are variable inputs being combined to produce a product (Y).

---

[2] Lawrence A. Bradford and Glenn L. Johnson, *Farm Management Analysis* (New York: John Wiley and Sons, Inc., 1953), p. 131.

[3] *Ibid*, p. 129 f.

Boulding[4] uses a three dimensional diagram to illustrate the concepts involved in finding the optimum combination of two inputs used in the productive process. A similar diagram is shown in Figure 1.

The solid lines are iso-value product lines connecting all points of equal value product being similar to a contour map with lines which connect all points of equal elevation. Each iso-value product line represents all combinations of the two inputs X_1 and X_2, which may be used to produce that given value product. Each successively higher iso-value product line represents a greater value of product. The inputs X_1 and X_2 are measured one along each axis. The broken lines are iso-cost lines. Each one of these lines represents all possible combinations of X_1 and X_2 which may be purchased for a given outlay or cost. The highest value product contour touched by one of these lines then, is the greatest value of Y which can be produced for a given outlay (cost) in securing the services of X_1 and X_2. The highest iso-value product line touched by an iso-cost line (AB) is the one which is tangent to that line at point T. The point of tangency indicates optimum proportions of X_1 and X_2 to use in the production of that value of Y. At this point, C units of X_1 and D units of X_2 are used. No other combinations of X_1 and X_2 which may be used for the same amount of outlay, will produce as many dollars as will this combination. At this point equation (2), this chapter, holds with respect to X_1 and X_2. By

[4] Kenneth E. Boulding, Economic Analysis (revised edition, New York: Harper and Brothers, 1948), pp. 671-712.

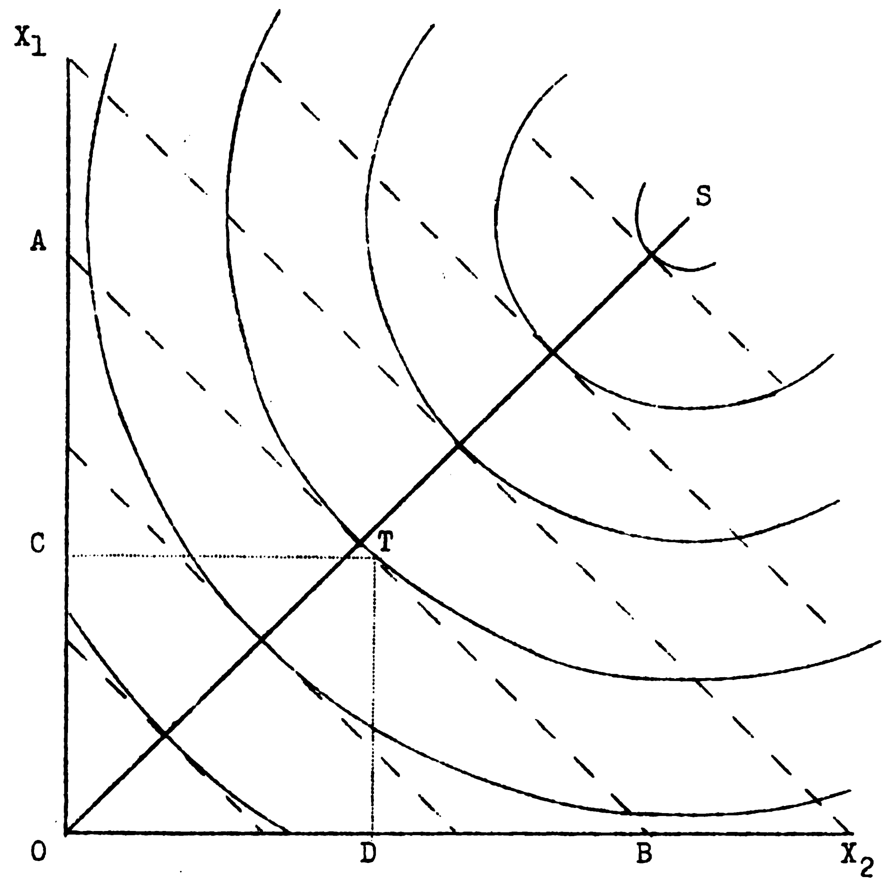


Figure 1. Iso-Value Product Lines with Iso-Cost Lines Superimposed to Locate Scale Line.

repeating this process, several points of tangency between iso-cost and iso-value product lines are located. Connecting these points results in a line (OS) which is called the scale line or line of optimum proportions. At all points along this line, equation (2), this chapter, holds.

Diagramatic illustration falls down when more than two variable inputs are used. The concept developed, however, holds for any number of inputs which may be used in a productive process. That is, optimum proportions of inputs are being used as long as the same ratio is maintained between the respective marginal value products and marginal factor costs of the different inputs.

The economizing principle is also used to determine the optimum level of output, that is, the high profit point. Assurance of a high profit point for a firm is given by the operation of the law of diminishing returns. This law holds that as a variable factor of production is added, in combination with a fixed factor, the total product will first increase at an increasing rate, second increase at a decreasing rate and finally the total product will decrease.[5] This assurance is made of course, assuming a relevant length of run, thus eliminating the rather unrealistic assumption that all factors are variable in the ultimate long run. As use of variable inputs is expanded in proportions dictated by the scale line, the law of diminishing returns will operate to cause the marginal value product of the inputs to fall to a point where they are just equal

---

[5] Bradford and Johnson, op. cit., p. 113.

to the respective marginal factor costs. The law of diminishing returns implies that increasing the use of one variable input will cause an increase in the marginal value product of the inputs not varied. Thus, there are two ways of increasing the marginal value product of an input; (1) contract use of that input or (2) increase use of supporting investment and expenditure inputs. The optimum level of resource use may be expressed as follows:[6]

$$(3)\quad \frac{MVP_{X_1(Y)}}{MFC_{X_1(Y)}} = \frac{MVP_{X_2(Y)}}{MFC_{X_2(Y)}} = ------ = \frac{MVP_{X_n(Y)}}{MFC_{X_n(Y)}} = 1$$

Effects of the law of diminishing returns on marginal value products of inputs combined in proportions dictated by the scale line may be seen more easily by using a two-dimensional diagram. In Figure 2, dollars are plotted along the vertical axis. Joint inputs X_1 and X_2, combined in the proportion dictated by the scale line, are plotted along the horizontal axis. The joint inputs (X_1 and X_2) are measured in money, thus a unit of the joint inputs is a dollars worth of the two inputs combined in the proportion dictated by the scale line. As the joint inputs (X_1 and X_2) are increased, given fixed amounts of other inputs (X_3 - - - - - X_n), the marginal value product of the joint inputs first increases at an increasing rate, second increases at a decreasing rate and finally decreases. The high profit point, for the conditions stated, is reached when the marginal value product falls to a point (H) where it is just equal to the marginal factor cost (MFC) of using the joint inputs. At point H, equation (3) holds with respect to the joint inputs X_1 and X_2.

---

[6] Ibid, p. 131.

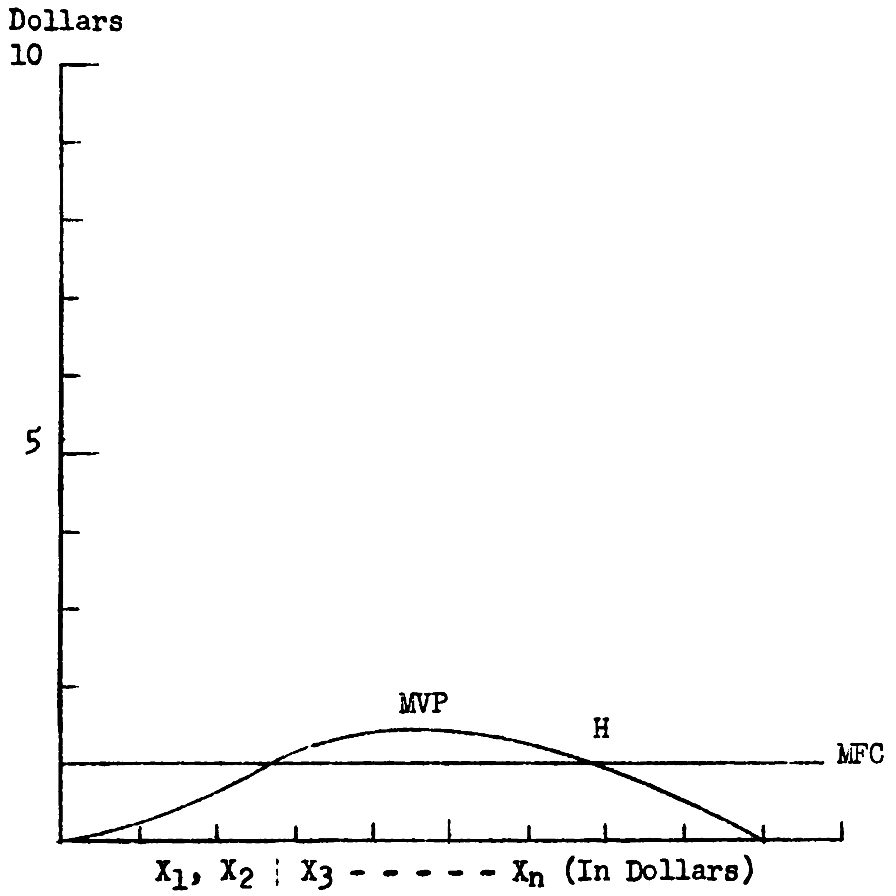


Figure 2. Location of the High Profit Point Using Joint Inputs of X_1 and X_2 (In the Proportion Dictated by the Scale Line) with Fixed Amounts of Other Inputs, X_3 - - - - - X_n.

The effect upon the product of increasing or decreasing the use of all inputs, indicates the returns to scale being experienced by the firm. Thus, if the marginal value products of the variable inputs decrease as all variable inputs are increased, the firm is experiencing decreasing returns to scale as a whole and with respect to each input. If the marginal value products of all the variable inputs increase as the variable inputs are increased, the firm as a whole is experiencing increasing returns to scale.

Application of Concepts to the Farm Business

The firm under consideration in this study is the farm business. The farm, more often than not, is a multiple enterprise firm, that is, it produces two or more products. These products combine to form one value product for the total farm business which is gross income.

Many of the inputs used in the production of farm products, may be substituted for one another while others must be combined in relatively fixed proportions. The characteristics referred to are substitutability and complementarity between inputs. While there are very few perfect substitutes or complements, their nature is well described in the words of Heady:[7] "Resources can be either technical complements or technical substitutes. They are, of course, technical complements. . . where a reduction in input of one factor cannot be replaced by an

---

[7] Earl O. Heady, Economics of Agricultural Production and Resource Use, (New York: Prentice-Hall, Inc., 1952), pp. 146-147.

increase in another factor. Factors are technical substitutes . . . when output can be maintained as resources are reshuffled; when one factor is reduced in quantity, a second factor must always be increased."

Two perfect substitutes are really one input with physical proportions unimportant and relative prices dominant in determining which will be used. Two perfect complements also are really one input with proportions used determined by the nature of the universe or technical conditions. In the case of two perfect complements, relative prices are unimportant in determining optimum proportions.[8]

Many of the inputs used on farms have good substitutes. For example, protein used in feeding hogs may be secured from soybean oil meal, tankage, fish meal and other sources. Other pairs of inputs such as labor and machinery may be substitutes within a certain range of production, but are complementary outside of this range.

Cows and forage crops provide an example of complementarity. As these two inputs can be substituted for each other over only a narrow range of production without affecting output they are fairly good complements. That is, definite physical limitations exist on shifting the proportions of these two inputs used.

Although, as pointed out earlier, perfect substitutes and complements are difficult to find in the farm business, degrees of substitutability and complementarity do exist to the extent that it is

---

[8] Notes taken on lecture given by Glenn L. Johnson to class in Production Economics, Michigan State College, 1953.

possible to group them so that numbers of them may be handled as one input when analyzing their effect upon the value product of the firm, gross income. This process of grouping or classifying is commonly followed by bankers, farmers, county agents and others to reduce the infinitely complex real world to terms manageable by finite human minds. Thus, such terms as working capital, livestock, machinery, out-of-pocket costs and real estate are in common everyday usage. The problem of grouping inputs into categories is discussed at a later point. (See page 19 ff.)

If an input is found to be earning more at the margin than it costs to use it, expansion in the use of this input can be expected to return additional net income or profits. By the same logic, if the marginal value product of one input being used is greater than that of another relative to their respective marginal factor costs, it may be concluded that the first input is being used too sparingly relative to the second input. For example, if it were found that the input category of cash expenses was returning one dollar and fifty cents for the last dollar spent while the return on the machinery investment was twenty-two percent, with interest, maintenance and depreciation charges totaling 20 percent, the logical action would be one of the following: (1) to increase cash expenses, (2) to decrease the amount of machinery, (3) to do both or (4) to add to both, though more rapidly to cash expenditures, until the condition specified in equation (3) holds true. The logic of this conclusion may be seen by comparing the ratios existing between the marginal value product and the marginal factor

cost for each of the two inputs. The ratio of $\frac{155}{100}$ is greater than the ratio of $\frac{22}{20}$. This same process may then be followed until the optimum combination of all inputs is realized.

The expansion in the use of all inputs to attain the optimum level of output usually is not easily accomplished in the farm business. Such obstacles as a shortage of capital, seasonality of production and unavailability of additional land and labor at costs which are justified by the anticipated additional returns may require that the process of expansion be spread over a considerable length of time.

Some of the marginal factor costs involved in making these comparisons must be determined subjectively. The return which a farmer will demand from the use of resources at his command is tempered by his judgement of the risks and uncertainties involved in production due to weather, diseases and prices. For example, plans involving the addition of land or buildings must be made with consideration for the price outlook for a number of years. Another factor, the value of which is usually arrived at subjectively is the labor which is supplied by the operator and his family. Some of the inputs making up the various input categories, have established market prices making it easy to calculate the addition to cost brought about by the use of them.

Marginal value products of inputs are less easily determined. Subjective estimates may be made, but these are likely to be very crude due to the limitations of human minds in handling the multitude of factors which influence these values.

It is the belief that estimates of marginal value products are of value to farmers, extension agents, vocational agriculture teachers, credit people and research workers in working with farm business managers which prompts the present piece of research. A way of making reliable estimates of marginal value products is fundamental to the science of farm management. Treatment of farm business data by the use of certain statistical techniques usually referred to as a Cobb-Douglas type production function probably is the best known method of arriving at these estimates. This is the method used in this study. A discussion of this method is taken up in the following chapter.

CHAPTER III

PRODUCTION FUNCTION ANALYSIS

The Cobb-Douglas Function

The use of production functions in the analysis of empirical data was given impetus in 1927-1928 by Paul H. Douglas,[1] of the University of Chicago (now a United States Senator), and Charles W. Cobb, of Amherst College.[2] The objective of their study was to test statistically the marginal productivity theory of income distribution. A function was fitted for all manufacturing in the United States by using indices of the amounts of capital and labor used and the value of product manufactured for the years 1900-1922.

The function fitted was linear in logarithmic form and was fitted by least squares regression. In non-logarithmic form the function is expressed: $P = bL^kC^{1-k}$. The three variables in the equation are defined as: P = the total value product of industry; L = labor used in production; and C = total fixed capital available for production. A restriction was imposed which made the sum of the exponents equal to one; this restriction was the equivalent of assuming constant returns to scale. In later studies this assumption was

---

1 Paul H. Douglas, Theory of Wages (New York: The Macmillan Company, 1934).

2 Charles W. Cobb and Paul H. Douglas, "A Theory of Production," The American Economic Review, Supplement, XVIII. (March 1928), pp. 139-165.

abandoned at the suggestion of Durand.[3] He pointed out that the assumption of constant returns to scale could be tested statistically in this way. Hence, the formula was revised and expressed as:[4]

$P = bL^kC^j,\ k \neq j \gtreqless 1.$

It is the latter type of equation which has been used in several studies estimating production functions in agriculture.

Application of the Function in Farm Business Analysis

One of the first to use statistical production functions in the analysis of farm business data was Gerhard Tintner of Iowa State College who used business records from 609 Iowa farms for the year 1942.[5] A similar study by Tintner and Brownlee was made, using farm records of 468 Iowa farms for the year 1939.[6] Both of these studies were based on data taken from farm account records. Heady[7] was the first

---

[3] David Durand, "Some Thoughts on Marginal Productivity with Special Reference to Professor Douglas' Analysis", Journal of Political Economics, XLV (December, 1937), pp. 740-758.

[4] Paul H. Douglas, "Are There Laws of Production?" The American Economic Review, XXXVIII, No. 1 (March, 1948), pp. 1-41.

[5] Gerhard Tintner, "A Note on the Derivation of Production Functions from Farm Records," Econometrica, XII, No. 1 (January, 1944), pp. 26-34.

[6] G. Tintner and O. H. Brownlee, "Production Functions Derived from Farm Records," Journal of Farm Economics, XXVI (August, 1944), pp. 566-571.

[7] Earl O. Heady, "Production Functions from a Random Sample of Farms," Journal of Farm Economics, XXVIII, No. 4 (November, 1946), pp. 989-1004.

to derive a production function using a random sample of farms. He used data for the year 1939 collected by interview from 738 Iowa farms. In more recent applications of this type of analysis, Fienup,[8] at Montana State College, used a random sample in a study of resource productivity on Montana dry-land crop farms. Drake,[9] at Michigan State College, followed the lead of Tintner and Brownlee using farm account records as the source of data and encountered, anew, some of the problems attending the use of farm account records in deriving production functions. (See page 25). Johnson,[10] at the University of Kentucky, used a Cobb-Douglas type production function in a study of the earning power of farms in the Purchase Area and Western Kentucky. A similar study was also made by Toon[11] at the University of Kentucky. In each of these studies, a "purposive sample" was used. The purposive sample can be somewhat smaller than random or farm account samples as they are drawn from a limited geographical area (usually a type of farming area

---

[8] Darrell F. Fienup, Resource Productivity on Montana Dry Land Crop Farms, Mimeograph Circular 66 (Bozeman: Montana State College Agricultural Experiment Station, 1952).

[9] Louis Schneider Drake, "Problems and Results in the Use of Farm Account Records to Derive Cobb-Douglas Value Productivity Functions" (Unpublished Ph.D. Dissertation, Department of Agricultural Economics, Michigan State College, 1952).

[10] Glenn L. Johnson, Sources of Income on Upland Marshall County Farms, Progress Report No. 1, and Sources of Income on Upland McCracken County Farms, Progress Report No. 2 (Lexington: Kentucky Agricultural Experiment Station, 1953).

[11] Thomas G. Toon, The Earning Power of Inputs, Investments and Expenditures on Upland Grayson County Farms During 1951, Progress Report No. 7 (Lexington: Kentucky Agricultural Experiment Station, 1953).

within a county), but cover a wide range with respect to the independent valuables (inputs). The current study is patterned after the work done at the University of Kentucky to a great extent in that it is based on a purposive sample.

In the application of a Cobb-Douglas type production function to the analysis of farm data, gross income is set up as the dependent variable. The independent variables are classes or groups of inputs which generate gross income. This type of mathematical function, along with economic theory and a factual knowledge of farm business, is capable of both determining causal relationships and measuring the degrees of relationship. The selection and grouping of the variable inputs into homogeneous categories bearing a causal relationship to gross income is done on the basis of a knowledge of agriculture and production economic theory.

Grouping of Inputs

One of the problems confronted in past application of the Cobb-Douglas function to the analysis of farm businesses has been that of classifying inputs in such a way that they may be grouped into independent categories. Johnson[12] offers the following conditions as guides to be followed in grouping the inputs into categories having a meaningful relationship with gross income and selecting a suitable unit of measurement.

---

[12] Bradford and Johnson, *op. cit.*, p. 144.

1. That the inputs within a category be as nearly perfect substitutes or perfect complements as possible.

2. That categories, made up of substitutes (a) be measured according to the least common denominator (often physical) causing them to be good substitutes and (b) be priced on the basis of the dollar value of the least-common-denominator unit.

3. That the categories made up of complements (a) be measured in terms of units made up of the inputs combined in the proper proportions (which are relatively unaffected by price relationships) and (b) be priced on an index basis with constant weights assigned to each complementary input.[13]

4. That the categories of inputs be neither perfect complements nor near perfect substitutes relative to each other.

5. That investments and expenses be kept in separate categories.

6. That maintenance expenditures and depreciation be eliminated from the expense categories because of the difficulty encountered in preventing duplication. (This means that the earnings of the investment categories must be large enough to cover maintenance and/or depreciation).

According to Johnson:[14] "The first three of the above conditions are desirable in order to insure that the inputs, within each category,

---

[13] As this study covered only one year (1952) it was unnecessary to construct price indices.

[14] <u>Ibid</u>. p. 145.

are combined in the proportions dictated by the scale line in the uncategorized production function: $Y = f(X_1 - - - - - X_n)$."

The fourth condition is consistent with the earlier observation that it is desirable to handle such groups of inputs as a single input. (See page 12).

The fifth condition is necessary due to the difference in returns expected from these two types of inputs. Cash expenses are expected to return at least one dollar for the last dollar spent. Expected minimum returns from investment categories, however, are those covering interest, maintenance, taxes and depreciation charges for a given year and are something less than one dollar per dollar of investment. If expenses and investments are included in the same category, the marginal value product has little meaning as a means of determining the optimum amount of the input category to use. Such biased marginal value products would be an indeterminate amount greater than the actual marginal value product of the investment component and less than the actual marginal value product of the expense component. If the last condition is complied with, marginal earnings on actual dollar investments can be estimated and each individual can establish a minimum rate of return to equate with marginal returns which he is willing to accept and which will cover interest, insurance, taxes, maintenance, depreciation, et cetera.

It is not to be assumed, of course, that all factors affecting gross income can be accounted for in any study of farm business records.

Weather and other factors over which man has no control are not included. Management is an important factor which has been excluded due to the difficulties of definition and measurement. The assumption concerning these and other non-studied variables is (1) that they are normally and randomly distributed and (2) that they do not cause bias in the estimated marginal value products of the studied variables.

The rules stated above are based on experience accumulated estimating value productivity functions from farm business records. It is worthwhile to note the groupings which were made in other studies of a similar nature. A study of these groupings reveals the progress which has been made in this respect.

Tintner and Brownlee,[15] used total product (X_1) measured by gross income as the dependent variable. Classifications of the independent input variables were: (A) land, measured in total acres; (B) labor, measured in man-months; (C) farm improvements, measured in dollars; (D) liquid assets, including non-breeding livestock, feed, seed and supplies, measured in dollars; (E) working assets, including breeding cattle, horses, tractors, crop machinery, trucks and farm share of the automobile, measured in dollars; (F) cash operating expense including livestock expense, feed purchased, repairs, fuel and oil for all machinery and equipment, measured in dollars.

Separate functions were derived for five different types of farms based on the source of income. These were: dairy, hogs, beef feeders and crops and general. The value of farm buildings (A) was

---

[15] Tintner and Brownlee, op. cit.

determined largely by the appraisal of the operator and the field man supervising records. As specific basis for appraisal was not indicated, estimated market values are presumed to have been used. In the working assets category (E) breeding cattle were grouped with power and machinery inputs. These are neither good substitutes nor good complements. Maintenance costs were included in cash operating expenses necessitating an adjustment in the return required to cover investments in machinery. The classification of inputs was essentially the same as the above in Tintner's earlier work.[16]

Heady[17] used total value product, including the sum of all cash sales; home consumption and inventory changes, as the dependent variable. Inputs were: (A) the value of land and buildings; (B) months of labor used; (C) the value of machinery and equipment including maintenance and operation costs; (D) the value of livestock on hand and purchased, and feed and livestock expense; (E) cash operating expense including fertilizer, twine, custom work and miscellaneous operating expenses. Heady chose to combine land and buildings (A). The value placed on real estate was that estimated by the farm operator. It will be noted that Heady did not separate all cash expenditure items from investments. Included in the same category were the value of machinery and equipment (investment) and operation costs (cash expenditure). Similarly, the

---

16 Tintner, op. cit.

17 Heady, "Production Functions from a Random Sample of Farms", op. cit.

value of livestock was grouped with feed and livestock expense which may account for the high marginal value product for forage and livestock. In addition, maintenance charges were in the same classification as the value of machinery and equipment necessitating a compensatory adjustment in the estimated marginal factor cost.

Fienup,[18] computed two functions; a crop function and a livestock function. In the crop function the dependent variable (Y) was the gross value of crop output including value of crop products plus miscellaneous receipts. The inputs included: (X_1), total crop acres; (X_2), total acres in wild hay and pasture; (X_3), man-months of labor attributable to crops; (X_4), value of total machine services including custom work hired, fuel, annual cost of machinery plus repairs and the annual cost of buildings and fences for crops; (X_5), total cash crop expenses including value of home grown seed sown, purchased seed, fertilizer, lime and spray.

In the livestock function, the dependent variable (Y_L) included the value of non-breeding stock at the end of the year, the value of non-breeding stock sold, the value of breeding stock raised and the value of livestock products used in the household. The independent variables were: (X_1) the value of total feed fed; (X_2) man months of labor expended on livestock; (X_3) the value of non-breeding stock at the beginning of the year, plus the value of non-breeding stock purchased, plus breeding herd depreciation; (X_4) the value of other livestock inputs

---

[18] Fienup, op. cit.

including the cost of buildings and fences attributable to livestock and miscellaneous livestock expenses.

Fienup apparently profited by the experience gained in previous studies in grouping inputs, as complements and substitutes were grouped in separate categories. Instead of estimating the marginal value product for the amount of investment in breeding livestock, machinery and improvements, annual charges were computed and handled as cash expenditures. The arbitrary allocation of the annual cost of buildings and fences between livestock and crops might have been avoided had the crop and livestock functions been solved simultaneously.

Drake[19] used farm account records. A study of his work indicates that if depreciation and maintenance costs are included in the current operating expense category, these costs should not be charged to the machinery investment category. The arbitrary nature by which depreciation charges are determined, the danger of confounding maintenance expenses with depreciation charges and, finally, the fact that maintenance expenses are for the purpose of maintaining asset values in contrast to earning incomes are some of the reasons for eliminating them from cash expenditures. Specific difficulties from the use of Michigan farm account records as a basic source of data arose. One of these is the problem of evaluating fixed assets such as buildings, land and cows. The practice in Michigan farm accounting is to carry these investment

---

19 Drake, op. cit.

items at the value assigned them when the farm accounts were set up. In many instances these values differ greatly from current values. Another problem encountered in using farm account records is the lack of homogeneity of farms keeping farm account records. Wide variations are found with respect to soil types, inputs used, commodities produced and types of farms. Still another problem encountered was that of separating productive from such non-productive expenditures as those on taxes, insurance, depreciation, and maintenance.

In the Kentucky studies[20] (X_1) gross income included all receipts from sales of crops, livestock and livestock products, plus changes in inventories and the value of products used in home consumption. The input categories were: land, in total acres; labor, in months; livestock and forage investment, in dollars; machinery investment, in dollars; and current operating expenditures, in dollars. These were designated X_2, X_3, X_4, X_5, and X_6, respectively. At this stage of development of the use of Cobb-Douglas techniques for analysis of farm business data, the lessons learned from previous studies were applied and are reflected in methodology employed. As previously noted, the feasibility of purposive sampling was recognized and adopted. In the grouping of inputs several points which are in contrast to the earlier studies may be seen. An attempt was made to group substitutes

---

20 Johnson, Sources of Income on Upland Marshall County Farms and Sources of Income on Upland McCracken County Farms, op. cit., and Toon, op. cit.

and/or complements into categories. For example, the complementarity existing between livestock and forage stands was recognized and these inputs included in the same category. Current operating expenditures were expanded to include more than "out of pocket expenses." All inputs from which a return of at least one dollar per dollar of expenditure is expected in the current year, were included in this category. Maintenance and depreciation charges for machinery were eliminated from computations. This made it unnecessary to arbitrarily select a depreciation rate and allows each farmer to select his own necessary rate of return to cover such charges.

Fitting the Function to Farm Data

The Cobb-Douglas function, expressed in natural numbers is written: $X_1 = b_1 X_2^{b_2} X_3^{b_3} - - - - - X_n^{b_n}$. The exponents ($b_i$'s) in the equation are the elasticities of the independent variables (X_i's) with respect to the dependent variables, gross income (X_1). In other words, the value of any exponent (b_i), indicates the percentage change in gross income associated with a one percent change in the respective input category, all other inputs held constant.

The function in the logarithms is linear and becomes:

$$\log X_1 = \log b_1 + b_2 \log X_2 + b_3 \log X_3 + - - - - - b_n \log X_n.$$

The function can be fitted easily by least squares regression to determine the constants (b_i's). This advantage offsets many of the disadvantages of the Cobb-Douglas function. Among the known mathematical functions capable of handling the shortcomings of traditional methods of farm record analysis, the Cobb-Douglas function is the easiest to compute. It should be pointed out that while the Cobb-Douglas method has many remaining shortcomings, it does handle many of the shortcomings of traditional methods of farm business analysis without (1) preventing use of traditional methods and, hence, (2) introducing new shortcomings. (See page 33 ff. for a discussion of the advantages and disadvantages of the Cobb-Douglas technique).

After the constants (b_i's) have been determined, they can be used to estimate marginal value products for each input category and gross income for the firm (farm business) over the range of data from which the elasticities were estimated. This is the principle advantage of Cobb-Douglas analysis over traditional methods of farm business analysis. The formula used in making these estimates may be stated in general terms as follows:

$$MVP_{X_i} = \frac{b_i \; E(X_1)}{X_i}$$ [21]

The estimated marginal value products thus derived for each input category may then be compared with the estimated cost involved in using the group of inputs in the manner discussed earlier. If these

---

[21] The term "$E(X_1)$" means expected gross income and is the antilog of $\log X_1$ in the estimating equation, $\log X_1 = \log b_1 + b_2 \log X_2 + b_3 \log X_3 + \text{- - - - -} \; b_n \log X_n$ when X_2 - - - - - X_n represent the proposed quantities of the inputs. $E(X_1)$, thus, depends on the quantities of all the inputs used as well as upon the quantity of X_i being used.

comparisons reveal that the ratios between the respective marginal value products and marginal factor costs of the variable input categories are considerably different, a proposed reorganization using modified quantities of inputs may be tried and modified until equation (2) (Chapter II) holds. The proposed plan may be tested by substituting modified quantities of the input categories into the original estimating equation. After determining the optimum combination of inputs, the use of all inputs combined in optimum proportions may be increased until the ratios between the respective marginal value products and marginal costs are all equal to one. At this point equation (3) (Chapter II) holds. Proposed reorganizations should involve quantities within the range of the data from which the estimates were made as the estimates should not be expected to hold far beyond this range. When making changes in quantities of one or more inputs used in combination with fixed amounts of other inputs the law of diminishing returns is expected to operate causing (1) the marginal value product of the increased inputs to fall; and, (2) the marginal value product of inputs held constant to rise.

In this type of function the sum of the exponents is not forced to equal one, therefore, increasing, decreasing or constant returns to scale for the business as a whole may be reflected. Decreasing returns to scale are indicated if the sum of the b_i's is less than one; increasing if greater than one; and constant if equal to one. The same is true for each individual input category. It is hardly reasonable to expect, however, to find an input category in a farm business, in which a one percent increase of that input category would result in a greater than one percent increase in gross income.[22] It is possible, however, and sometimes happens that negative elasticities are derived for certain input categories. Tintner and Brownlee[23] state: ". . . . negative elasticities, within the range of inputs on most farms are meaningless. It seems unlikely that production should actually decrease if certain factors of production are increased."

Selection of Sample Farms

Another problem presents itself in the use of this type of analysis. That problem arises in selecting farms from which data to be analyzed are taken. The purpose of the analysis is to construct estimates of the marginal value products of input categories, these estimates to be used in determining better allocations of resources on individual farms.

More reliable marginal value product estimates are secured if the farms from which data are secured are relatively homogeneous with respect to non-studied inputs and variables. It probably is impossible to find a group of farms which is truly homogeneous in any respect. Care in selection, however, will permit an approach to this goal with respect to the following conditions.

---

22 This does not, however, eliminate the possibility of increasing returns to individual inputs. Boron, for example, on boron deficient soils might have this effect.

23 Tintner and Brownlee, op. cit., p. 568.

First, the farms in the group must have about the same inherent productive capacity. This requirement may be fulfilled to a great extent by choosing farms within a limited geographic area and having about the same soil type associations. It is possible that this condition could be relaxed if a reliable index of land capacity for each farm could be devised, and these indices used to weight the number of acres in each farm. A method of classifying farms in such a manner is the subject of a study now being conducted at Michigan State College.[24]

A second condition is that all farms must be using about the same technology. This condition is rather easily met if inputs are grouped according to the rules discussed earlier and the selection is based on the condition that the same input categories are involved.

The third and last condition is that the inputs within each input category should be combined in the best possible proportion on each individual farm. This end may best be realized if the data used cover only one year thus minimizing the effects of weather and price changes and the categories are set up on the basis of previously discussed rules for setting up input categories

Under these three conditions it is reasonable to expect that the same amounts of inputs would have about the same effect on gross income from farm to farm.

---

[24] Study being conducted by R. O. Kenworthy under the supervision of L. H. Brown, Department of Agricultural Economics, Michigan State College.

In order to get unbiased estimate of the b_i's (and hence of the marginal value products) all the farms from which the data are secured should not be operating at competitive equilibrium. Brofenbrenner[25] points out that such a condition would result in an interfirm curve forming an envelope of and tangent to the intrafirm (total product) curves for each firm at the point of long run competitive equilibrium. Under conditions of long run competitive equilibrium, the marginal productivity of an input would be the same whether measured along a single intrafirm productivity curve or an interfirm curve. Thus, with the exception of the special case, namely, all firms experiencing constant returns to scale, the marginal value productivity of an input, derived from the interfirm production curve[26] would be less than the marginal productivity, as measured on the intrafirm production curves at points of contact for those quantities of input below the quantity to keep the firm at competitive equilibrium. The marginal productivities of larger amounts of inputs would be overestimated. A group of perfectly adjusted firms would yield data reflecting a high degree of intercorrelation between each independent variable and the other independent variables.

---

[25] Martin Bronfenbrenner, "Production Functions: Cobb-Douglas, Interfirm, Intrafirm," Econometrica, XII, No. 1 (January, 1944), pp. 35-44.

[26] In this case the interfirm curve is not an envelope curve of the intrafirm curves as the latter cross the interfirm curve from below rather than being tangent to it.

Since data taken from firms operating at competitive equilibrium would not reflect the degree of diminishing returns experienced by the firms, a fairly wide range of data taken from imperfectly adjusted firms should be used. The range of data also influences the reliability of the regression coefficients. As the range (hence the variance) of data is increased, the standard errors of the regression coefficients are reduced.[27] The lack of range in data then, may reduce the reliability of the regression coefficients by causing a high standard error in the regression coefficients.

Advantages and Disadvantages of the Cobb-Douglas Technique

Certain of the difficulties confronted in using a Cobb-Douglas type production function are centered around the problems of methodology in handling empirical data. These problems, however, are common to all types of farm business analyses. For example, no known method exists by which the important factor of management may accurately be measured. An attempt was made in this study to evaluate this factor. The results obtained were inconclusive. In several instances, farm operators were judged to be good managers relevant to several years of operation but the farms they operated were in poor adjustment in the year 1952 as judged on the basis of marginal value productivity. There are

---

[27] Mordecai Ezekiel, Methods of Correlation Analysis (Second edition, New York: John Wiley and Sons, Inc., 1949), p. 360.

of course, other inputs for which no measurement is attempted and which may introduce bias if they are not randomly and normally distributed.

At its present stage of development, the Cobb-Douglas technique is not useful in analyzing a group of farms having widely divergent enterprises. The result is that a group of farms to be analyzed must be producing similar products. The effect of an input category may be considerably different upon a gross income derived from the sale of dairy products versus gross income derived from the sale of fruit. This problem is avoided by choosing farms which are all primarily either dairy farms, beef farms, crop farms, general farms, et cetera. The problem of determining enterprise relationships by production function analysis must await the development of suitable simultaneous estimating equations.

The remaining disadvantage to be mentioned here is one which is inherent in the function. That is the limitation imposed due to the inability of the function to simultaneously handle more than one stage of production.[28] The estimated regression coefficients are constant for the entire function thus causing this restrictive limitation. This limitation is not unduly serious, however, as the relevant stage of production to analyze is that in which diminishing marginal returns are experienced, that is, Stage II. It is believed that the assumption of constant elasticity is preferable to assuming constant marginal value products as implied by traditional methods.

---

[28] Stigler, op. cit., pp. 113-125.

It would not be expected that farms operating in Stage III with respect to gross income would be found. It is possible, however, that both Stage I and Stage II could be represented by farms in a given area. The portion of Stage I represented in the data taken from a group of farms primarily in Stage II is believed to be so small that no serious error is introduced in the estimate of the production function.

The above disadvantages are outweighed by the advantages which may be realized by using this technique. Tintner[29] gave as his reasons for using this function rather than any other, the following:

1. It gives immediately elasticities of the product with respect to the factors of production.

2. This form of the production function permits the phenomenon of decreasing marginal returns to come into evidence without using too many degrees of freedom.

3. If the errors in the data are small and normally distributed, a logarithmic transformation of the variables will preserve the normality of a substantial degree.

In addition to those listed by Tintner, Johnson has pointed out the following advantages:[30]

1. The shortcomings of this technique are also either obvious or hidden shortcomings of former methods of analyzing farm records.

---

[29] Tintner, op. cit., pp. 26-27.

[30] Statement by Glenn L. Johnson, Department of Agricultural Economics, Michigan State College.

2. In making estimates of the marginal value productivity of one input category, it is unnecessary to assume the earning power of other input categories.

3. The estimates of the marginal value products obtained by this method are capable of reflecting the influence of supporting inputs and investments.

The chief advantage of the Cobb-Douglas technique is its ease of computation. The simplicity of least-squares regression alone offsets many disadvantages. A minimum of assumptions is required, the main ones being (1) that disturbances be independently and normally distributed; and, (2) the constant elasticity assumption. Wold[31] very aptly summarizes this disturbance assumption in stating, "In essence, the only assumption required is that the disturbance factors should be uncorrelated with the regressors, and this is a minimal requirement for validity of the approach, since the regression residuals will automatically be uncorrelated with the regressors." Wold[32] further points out that the possibility of devising better methods cannot be excluded, but that ". . . . when it comes to practical applications their advantages will always have to be balanced against the substantial advantages of the least-squares method of being highly flexible as regards the underlying assumptions and very simple as regards the numerical computations."

---

[31] Herman Wold, Demand Analysis, (New York: John Wiley and Sons, Inc., 1953), p. 56.

[32] Ibid, p. 59.

CHAPTER IV

SAMPLING PROCEDURE AND MEASUREMENT TECHNIQUES

The Sample

The data used in this study were taken from thirty-three farms in Ingham County, Michigan for the calendar year of 1952. Desired information for each farm was taken from farm records and expanded by personal interview.

In selecting the sample farms an effort was made to comply with the rules and conditions outlined in the preceeding chapter. Compliance with these conditions obviously limited the number of farms from which the sample was drawn. The general conditions delimiting the sample were as follows:

1. All farms included in the sample were on soil type associations rated as good or good to excellent.[1] Miami loam, Conover loam and Hillsdale sandy loam were the main soil types included with lesser amounts of Brookston and Griffin loams interspersed. It is believed the differences which exist in the inherent productive capacity of soils from one farm to another are randomly and normally distributed and not important enough to upset conclusions.

---

[1] United States Department of Agriculture, Bureau of Chemistry and Soils, <u>Soil Survey, Ingham County, Michigan</u> (Washington: United States Printing Office, 1941).

2. On all farms included in the sample, dairy was the main enterprise. Minor enterprises included beef cattle, hogs, poultry, sheep and cash crops consisting mainly of winter wheat. This condition is representative of many Ingham County farms and of farms in many other Michigan farming areas.

3. All farms included in the sample were using about the same inputs in the productive enterprises.

4. The inputs making up each category on the farms of the sample were assumed to be combined in near optimum proportions. The plausibility of this assumption depends in part on how good a job was done of getting sets of complements and substitutes together in the same input category.

5. All of the farms in the sample were believed to be producing in Stage II.[2]

The sample drawn was a "purposive" one in the sense that an effort was made to secure as wide a range of data as possible relevant to gross income and to quantities and proportions used of each of the input categories. The purpose of seeking range was to insure greater reliability in the estimates of the regression coefficients derived from the data. The need for range and the problems which arise when sufficient range is not present in the data were discussed in Chapter III.

---

[2] This belief existed prior to computing the regression coefficients. The sum of the regression coefficients was 1.076515 indicating slightly increasing returns to scale with respect to the variable inputs measured.

During the process of securing the data, a check on the range being obtained was sought by plotting several pairs of input categories on graphs. The pairs of input categories selected were those which were believed most likely to show a high degree of correlation.

Figure 3 presents one of the graphs plotted for this purpose while gathering the data for this study. An attempt was made to secure as much scatter on the graphs as feasible. If it was found, for example, that the dots representing the amounts of labor and machinery used on the farms tended to fall along a line, a high degree of correlation between the two input categories was indicated. By plotting the data as gathered, a basis for judgement was provided for selection of farms to be included in the sample. If, for example, a relatively high correlation was indicated between labor and machinery, farms were sought having both greater and lesser amounts of machinery relative to the amount of labor used.

In spite of these precautions, fairly high correlations were found to exist between some of the pairs of input categories. The simple correlation coefficients for all possible combinations using two inputs at a time (with the exception of buildings) were:

$rX_2X_3 = .6087$	$rX_2X_4 = .7429$	$rX_2X_5 = .6620$	$rX_2X_6 = .6925$
$rX_3X_4 = .6495$	$rX_3X_5 = .7191$	$rX_3X_6 = .7163$	
$rX_4X_5 = .6770$	$rX_4X_6 = .7339$		
$rX_5X_6 = .7877$			

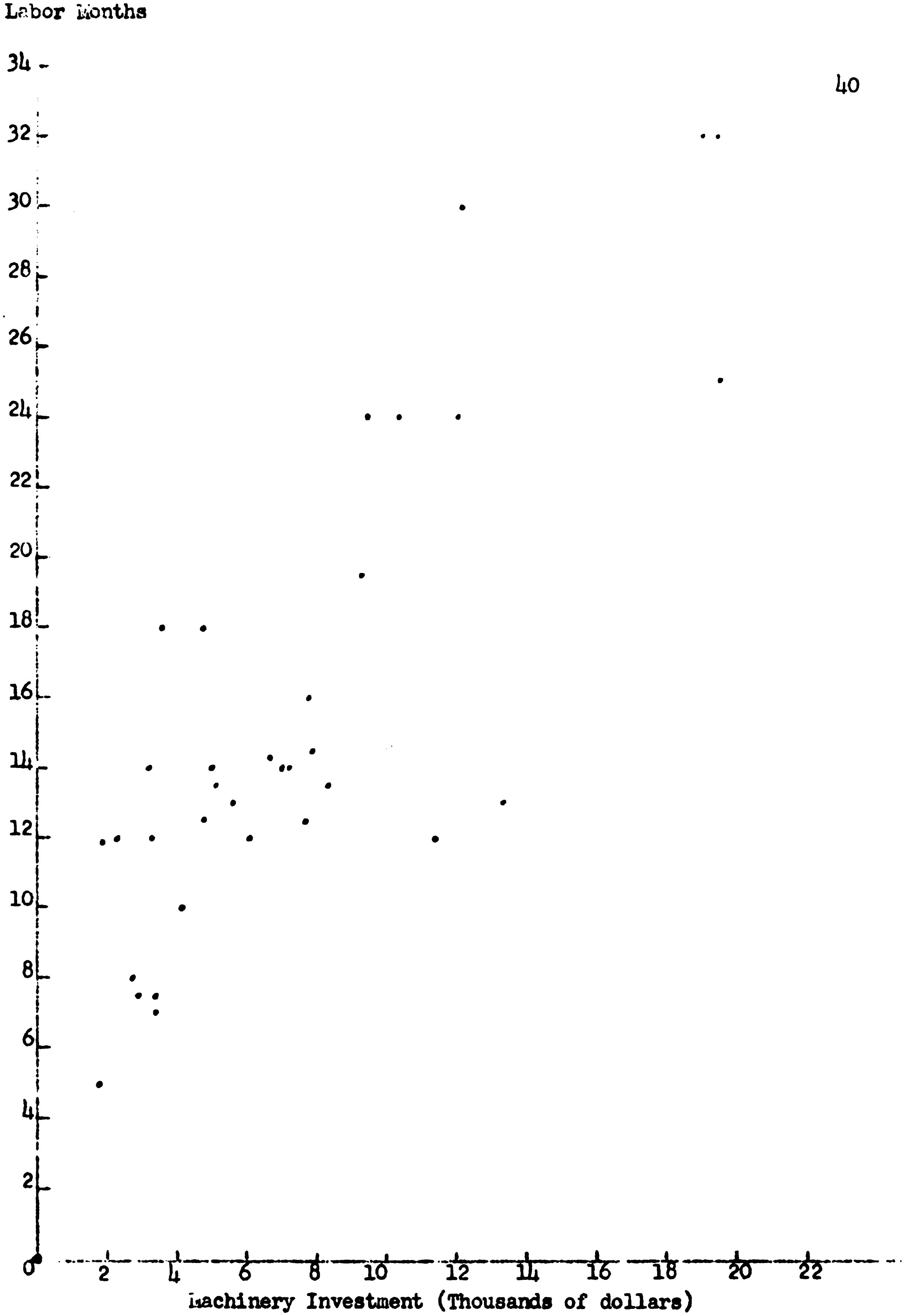


Figure 3. Graph Used as Check on Range of Data for Labor and Machinery.

The input categories (X_i's) are: (X_2), tillable acres of land, (X_3) months of labor, (X_4) expenses, (X_5) livestock and forage investment and (X_6) machinery investment.

These results indicate that the farms included in the sample are fairly well adjusted. This would be expected in an area such as Ingham County which has long been settled and in which farmers have had an opportunity to adjust to existing conditions to a great extent.

The Data

As previously noted, the data taken from each of the thirty-three farms included:

X_1, gross income, the dependent variable, and the independent variables

X_2, land, in tillable acres

X_3, labor, in months

X_4, current operating expenses, in dollars

X_5, livestock and forage investment, in dollars

X_6, machinery investment, in dollars

X_7, buildings, in animal units

The components of gross income and of each of the independent input categories is shown in Figure 4. In general this is self explanatory. The methods of computing some of the individual components, however, are explained below.

Gross income included all sources of value received by the sale, use or ownership of products and services produced by the productive resources of the farm. Such sources of income as government P.M.A. payments,

Gross Income (X_1)			
Cash Receipts	Value of Farm Products Consumed in Household	Change in Livestock Inventory	Change in Crop, Seed and Feed Inventories
Dairy and Poultry Products Livestock and Livestock Products Crops and Timber Products Custom Work	(Excluding Rental Value of Dwelling)	Ending inventory of all livestock minus beginning inventory of breeding livestock	Ending inventory minus beginning inventory

Land (X_2)	Labor Months (X_3)	Expenses (X_4)	Livestock-Forage Investment (X_5)	Machinery Investment (X_6)	Buildings (X_7)
Tillable Acres with usual complements of fences and drainage facilities	Operator Family Hired	Cash Machinery Gas, Oil Grease Livestock Feed Veterinary Breeding Fees Registration Fees Crop Fertilizer, Seed Feeders and Chicks Purchased Miscellaneous Beginning Inventory of Feeders Beginning Value of Annual and Biennial Forage Stands Beginning value of Perennials Destroyed	Average Investment in Breeding Stock* Average Investment in Perennials Forage Stands**	Average Investment in Machinery	Animal Units of Buildings

* Average investment equals value at the beginning of year, plus a proportional cost for purchases, minus a proportional credit for sales.

** Average investment in perennials equals the value at the beginning of the year plus the value of seed used plus the value of lime used minus a proportional credit for perennials destroyed.

Figure 4. The Components of Gross Income and of the Independent Input Categories.

investments in other businesses and the rental value of the farm home were thus excluded.

In computing the change in crop, seed and feed inventories, the value of growing wheat was included. The base value per acre of wheat was established to be the per acre cost of establishing a stand of wheat, including labor, machinery and seed costs.[3] This base value was then adjusted by the per acre cost for fertilizer used for the 1952 wheat crop on each farm. It was believed that the ending inventory value of growing wheat was fairly accurate even though the adjustment for fertilizer was based upon applications made on the 1952 crop. Farmers indicated that they fertilized wheat at about the same rate each year and there was little change in the price of fertilizer.

Under expenses were included all inputs which would be expected to return at least a dollar for each dollar spent in the current year. Thus, the expense figure might be referred to as productive cash expenditures. The beginning inventory of feeders, the beginning value of annual and biennial forage stands and the beginning value of perennial forage stands destroyed were included in expenses as these inputs are expected to yield at least a dollar for dollar return in the relevant year.

In accordance with the sixth condition stated on page 20, maintenance and depreciation charges were excluded from machinery expense.

---

[3] Unpublished data on estimated establishment costs for forage crops and small grains compiled by H. S. Wilt, Department of Agricultural Economics, Michigan State College.

The total value of fertilizer used was treated as an expense as the farmers interviewed indicated that about the same amount of fertilizer was used over the entire farm each year as a result of following a planned crop rotation. Where this is not the usual practice, it may be necessary to treat as an investment in forage a portion of the fertilizer applied to perennial forage crops. That portion treated as an investment is the estimated value of the fertilizer applied but not used by the crop in the current year. Under the usual practices indicated, however, it appeared reasonable to believe that the value of the unused residual was about offset by the residual value of fertilizer carried over from applications made on perennial forage crops the preceding year.

The values of perennial forage stands used in computing the average investment in perennial forage stands were based on the estimated per acre cost of establishing the stands.[4] The establishment costs were then adjusted according to the age and condition of the stand. A life expectancy of four years was used on alfalfa and alfalfa mixtures and two years for ladino clover mixtures.

The prices used in computing investments, inventories and the value of farm products consumed in the farm household were estimated at 1952 market prices as indicated by the farmer. If no valid estimate of the market price could be given, the price used was the average of the

---

[4] Ibid.

mid-month prices for Michigan, 1952.[5] A value of two dollars and twenty-five cents per first year laying hen was used in computing the livestock investment.[6]

As no market prices were available for corn silage, grass silage and cord wood, the values commonly used by the Farm Management Extension Staff at Michigan State College were used. These values were: ten dollars per ton for corn silage; eight dollars per ton for grass silage, and five dollars per short cord for cord wood.

Buildings were measured in animal units. As this is a departure from previous methods, a more detailed explanation will be undertaken.

The purpose of measuring farm buildings in animal units was to avoid the difficulties involved in placing a dollar value on farm buildings. This difficulty arises as there is no market for farm buildings in the sense that they are commonly bought and sold separate from the land with which they are associated. If current representative sale prices of farms were used as a basis for appraising farm buildings, the farm being appraised would first have to be compared with representative farms to determine the total value. Secondly, some portion of the total value of land, farm dwelling and farm buildings would have to be rather arbitrarily allocated to farm buildings. There is no known method by which the proportion allocable to farm buildings may accurately be determined.

---

[5] United States Department of Agriculture, Bureau of Agricultural Economics, <u>Agricultural Prices</u>, Washington, D. C.

[6] This figure was supplied by H. E. Larzelere, Department of Agricultural Economics, Michigan State College.

Another possible basis for determining investments in farm buildings is to determine the cost of replacing existing structures with the same type of construction and adjust the resulting figure for each building according to the age and condition of the building. This method of course, involves subjective estimates used to adjust for condition and the arbitrary selection of an expected life for each building to use as a basis for depreciation. This method ignores the problem resulting from the changes in material and labor costs that have taken place since many existing farm buildings were built and the concomitant changes in types of construction used.

Even if these difficulties of determining replacement costs could be overcome, the real problem of determining value remains unsolved as the value of a fixed input is determined by the income it earns. Existing buildings are ordinarily fixed assets with respect to the farm business and there is no market price which reflects their value as an earning asset. Bradford and Johnson[7] state: "If . . . . . an asset is presently earning an income making it worth not more than replacement cost and not less than opportunity cost, then no reason exists for varying it and it remains a fixed asset." Only in the special case where replacement cost and capitalized earning value of buildings are equal would the replacement cost reflect use value. In other instances replacement costs are ordinarily greater than use value.

---

[7] Bradford and Johnson, op. cit., p. 133.

Fienup[8] treated farm buildings as a separate expense item. The value of buildings was multiplied by .025 to determine the annual cost of buildings. Using this method, buildings would be expected to yield a marginal value product at least equal to the annual cost of using them. In addition to the problem of determining values of farm buildings, this method involves the further problem of arbitrarily selecting a percentage of value to use as a constant in determining the annual cost.

A method of measuring farm buildings in animal units was devised by the author to provide a measurement of the physical quantity of buildings on each farm. The measure was based on the capacity of each building for livestock and/or crop storage. By expressing building capacities in terms of a common denominator (animal unit) a quantitative measure was assigned to each building.

A building animal unit was defined as the equivalent of the replacement cost of shelter and hay storage for one mature dairy cow housed in a conventional two story, stanchion type dairy barn. The cost for a dairy cow was the average estimated replacement cost of housing and hay storage per cow of a twenty cow dairy barn with space for the usual complement of calves and hay, as computed by the cubing method. A building animal unit of chickens is the number of chickens which can be housed in the same value (replacement cost) of buildings

---

[8] Fienup, _op. cit._, p. 44.

as one mature dairy cow and her hay. The same is true with respect to hogs, sheep, et cetera.

Replacement costs per dairy heifer or steer, sow and litter, feeder hog, ewe or ram, feeder lamb, hen, broiler, bushel of small grain, crate of ear corn, ton of silage and milk house capacity for one cow were computed, based on buildings of typical size and capacity for the relevant use.

Costs of replacing buildings for an animal unit of capacity (not necessarily the same type of construction) were used as weights in arriving at their relative use values. The method used in estimating replacement cost was the cubing method.[9] To find the cost of constructing a building by this method it is first necessary to determine into which of ten classes of buildings it falls. These classes are based on types and sizes of construction used for various purposes. For each class of building a set of constants is given which are based on the amount of construction lumber, finish lumber, roofing, labor and gravel used per cubic foot in constructing that particular class of building. These constants are multiplied by current prices of the construction cost per cubic foot.[10] An amount in cents per cubic foot is added for miscellaneous paint, cement, hardware and equipment given for each class of building. The total cost per cubic foot is then multiplied

---

[9] John C. Wooley, Farm Buildings (Second Edition, New York: McGraw-Hill Book Company, Inc., 1946), pp. 21-23.

[10] Prices of materials were secured from local dealers.

by the number of cubic feet in the building to find the total estimated cost. A correction factor is given to adjust cost for the size of building. The amount added per cubic foot for miscellaneous paint, cement, hardware and equipment was adjusted to 1952 prices by the index of prices paid by farmers for building and fencing materials.[11]

Silos and hog houses were not included in the ten classes of buildings. Construction costs used for these buildings were costs actually reported by farmers in the area who had recently built typical buildings of this sort.

The size and capacity of buildings on each farm were recorded and converted to animal units by the following formula:

$$\frac{\text{(Replacement cost per unit) (Number of units of capacity)}}{\text{Replacement cost per dairy cow}} = \text{Animal Units of buildings.}$$

The conversion factors used in these computations are shown in Appendix A.

The cubing method of estimating costs is based on Missouri conditions and may not be an accurate method of estimating replacement costs of farm buildings under Michigan conditions. A study of actual building costs over the past five years for typical farm buildings in Michigan is being conducted by Professor E. B. Hill, of Michigan State College, in cooperation with the Farm Credit Administration. This study when completed, should prove to be very valuable in estimating replacement costs for farm buildings in the State.

---

[11] United States Department of Agriculture, Bureau of Agricultural Economics, The Farm Cost Situation (Washington, D. C.).

While this method of measuring farm buildings was devised in an attempt to avoid the obvious difficulties involved in placing a dollar value on buildings, a further possible advantage gained by the use of this method was the division of real estate into land and buildings, thus permitting estimates of the marginal productivities of each to be made.

CHAPTER V

FITTING THE FUNCTION

Statistical Results and Evaluation

The data gathered from the 33 farms were summarized to arrive at figures for gross income and for each of the input and/or investment categories. These figures were then converted to logarithms. The method followed in fitting the Cobb-Douglas functions was that presented by Ezekiel for fitting a linear multiple regression equation and correlation.[1] Hence, the normal equations were solved by the Doolittle method to calculate the regression coefficients and their standard errors.

The regression coefficients were found to be:

$b_2 = .299873$ for land

$b_3 = .042435$ for labor

$b_4 = .259661$ for productive cash expenses

$b_5 = .483610$ for livestock and forage investments

$b_6 = .133895$ for machinery investments

$b_7 = -.176928$ for building units

It will be noticed that the regression coefficient b_7 was negative, indicating that for the farms sampled, the last animal building

[1] Ezekiel, op. cit., 455-485.

unit used returned no positive marginal value product (measured at the geometric mean). This input was later omitted from the calculations as, in concurrence with Tintner and Brownlee's statement[2] as regards this situation, it does not appear likely that increasing the quantity of buildings would actually decrease gross income. When animal units of buildings were not included, the multiple coefficient of determination was reduced by only .002, obviously an insignificant amount.

The regression coefficients for the five remaining independent variables along with their respective standard errors were recomputed to be:

$b_2 = .211072 \pm .098678$ for land

$b_3 = .041663 \pm .130825$ for labor

$b_4 = .250010 \pm .114316$ for productive cash expenses

$b_5 = .448209 \pm .083937$ for livestock and forage investments

$b_6 = .125561 \pm .109299$ for machinery investments

The sum of the regression coefficients was 1.076515. As this sum is greater than one, increasing returns to scale are indicated. This sum, it appears, is not significantly greater than one, hence it will not be concluded that increasing returns to scale exist on Ingham County dairy farms.

---

2 Tintner and Brownlee, op. cit., p. 568.

The constant (log a) was computed and found to be .425289. The regression coefficients and the constant (log a) fit into the logarithmic form of the Cobb-Douglas function as follows:

$$\log X_1 = .425289 + (.211072)\log X_2 + (.041663)\log X_3 + (.250010) \log X_4 + (.448209)\log X_5 + (.25561)\log X_6$$

The multiple correlation coefficient (R) was found to be .96. Under conditions of random sampling with five independent variables and one dependent variable, a multiple correlation this high would be expected in one sample out of twenty, on the average, if the true multiple correlation coefficient was .89.[3] Thus, the degree of correlation is highly significant. Due to the selection of extreme values in the sample, the value of the sample multiple coefficient of correlation should be expected to be higher than that prevailing in the universe though not higher than for similarly selected samples.[4]

The coefficient of determination was computed to be .92, indicating that ninety-two percent of the variance in the logarithms of the dependent variable (gross income) was associated with the independent variables. The coefficient of determination was found to be significantly different from zero at three standard deviations according to the "F" test of variance.[5]

---

[3] Ezekiel, *op. cit.*, p. 508.

[4] Ezekiel, *op. cit.*, p. 360.

[5] Frederick E. Croxton and Dudley J. Cowden, *Applied General Statistics* (New York: Prentice-Hall Inc., 1939), pp. 776-777.

The eight percent of variance unexplained by the independent variables is due to such factors as management and weather conditions, measurements of which were not attempted in the study. Other sources of unexplained variance may have been due to differences in soils from one farm to another and differences in appraising the value of investments. The assumption as regards the influences of these non-studied variables on gross income is that they were normally and randomly distributed.

The logarithm of gross income, ($E X_1$), at the geometric mean, was 4.00870 the antilog of which is 10,202 dollars to the nearest dollar. The standard error of estimate ($\bar{S}$) of the dependent variable was found to be .090288. Under conditions of random sampling, given the price and weather conditions prevailing in 1952, sixty-seven percent of the time the logarithms of actual gross income would be expected to fall within the range of 4.008700 $\pm$ .090288 or, in natural numbers, between 8,287 and 12,560 dollars. This means that, on the average, one farm out of three of the usual organization would be expected to have a gross income greater than 12,560 or less than 8,287 dollars. The standard error of estimate for natural numbers is smaller for small farms than for large farms.

The computations and the resulting estimated marginal value products for the usual organization[6] are shown in Table I.

---

[6] The term "Usual organization" is used to indicate an organization having the geometric mean (G) amounts of the input categories for the farms included in this study.

TABLE I

USUAL ORGANIZATION AND ESTIMATED MARGINAL AND GROSS VALUE PRODUCTS THIRTY-THREE INGHAM COUNTY FARMS, 1952

Input category	Quantity of inputs	Log GX_i*	b_i's	Log $GX_i \cdot b_i$	MVP** (dollars)
X_2	130 A.	2.1141	.2111	.4462	16.56
X_3	14 mo.	1.1486	.0417	.0479	30.19
X_4	$3,348	3.5247	.2500	.8812	.762
X_5	$7,126	3.8528	.4482	.7269	.642
X_6	$6,803	3.8327	.1256	.4812	.188

Log constant (a) = .425289

Log X_1 (Gross Income) = Log a + $\sum(b_i \cdot G_{X_i})$ = 4.008700

* (G) is designated, geometric mean

** $MVP_{X_i} = \dfrac{b_i(GX_1)}{G_{X_i}}$

Marginal value product estimates, it is seen from the above, are derived directly from the regression coefficients (b_i's). Thus, the problem of establishing the significance of marginal value product estimates is closely related to the problem of establishing the significance of the regression coefficient estimates.

The most obvious, but far from appropriate, way of testing the regression coefficients for significance is to test them against zero as a null hypothesis. The regression coefficient b_5 (for livestock and forage investments) was significantly different from zero at the one percent level; b_2 (for land) and b_4 (for productive cash expenses) at the five percent level of significance; b_6 (for machinery investments) was not significantly different from zero at the five percent level of significance and the standard error of b_3 (for labor) was larger than b_3.

As the marginal value products of investments are not expected to be as high as those for expenses or direct inputs, it is not logical to test all the b_i's (from which the marginal value products are estimated) against the (same) null hypothesis.

An alternative procedure is to compare the estimated b_i's with the b_i's necessary to yield marginal value products equal to a set of minimum expected returns or reservation prices for the different input categories. The minimum expected return for an input category varies from farm to farm as costs and subjective values vary with business position, family situations, and degrees of price and weather uncertainty. On the basis of observation and discussions with farm management extension specialists at Michigan State College, the following was accepted as a reasonable set of minimum expected returns or reservation prices:

Land.	7.50 dollars per tillable acre
Labor	80.00 dollars per month
Expenses.	1.00 dollar per 1.00 dollar of expenditure
Livestock and forage investment	40 - 50 percent
Machinery investment. . .	15 - 25 percent

A minimum expected return of seven dollars and fifty cents per acre to land was based on five percent interest rate with land valued at 150 dollars per acre. Although wage rates for farm labor in Ingham County generally exceeded 80 dollars per month in 1952,[7] this figure was selected in recognition of the amount of family labor employed. A range of from 40 percent to 50 percent return on investments in livestock and forage was believed reasonable in view of the high rate of depreciation experienced on cows and perennial forage stands such as alfalfa-brome mixtures, that is, the typical cow has a remaining productive-life expectancy of three to four years while the typical alfalfa-brome stand has a remaining productive-life expectancy of one to two years. The return on machinery investments must cover depreciation, maintenance (including housing, if any) and insurance. The minimum return necessary to cover these charges varies from farm to farm depending on the care given machinery, whether the family is borrowing money at four and one-half percent on a land mortgage or is using 18 percent consumer credit, and the age and value of the machinery. A range of from 15 percent to 25 percent returns on machinery investments allows a fairly wide latitude in recognition of these differences.

The estimated minimum expected returns were substituted in the marginal value product equations. These equations were, in turn, solved for the b_i's which would yield these minimum expected returns. Table II compares the estimated regression coefficients and the regression coefficients necessary to yield the minimum expected returns.

---

[7] Karl A. Vary, "Wage Rates Reported by Farmers", Michigan Farm Economics (East Lansing: Cooperative Extension Service, Department of Agricultural Economics, Michigan State College, August, 1953). In the area which includes Ingham County, the range was from 60 dollars to 125 dollars per month plus room and board, with the common rate reported as 125 dollars per month plus room and board.

TABLE II

COMPARISON OF ACTUAL ESTIMATED b_i's AND THE b_i's NECESSARY TO YIELD THE ESTIMATED MINIMUM MARGINAL VALUE PRODUCTS

b_i	Actual b_i's	b_i's to yield minimum return	Difference (Actual Minimum)
b_2	.211072	.095571	.115501
b_3	.041663	.110409	-.068746
b_4	.250010	.328170	-.078160
b_5	.448209	.279396	.168813
b_6	.125561	.133366	.007805

The estimated b_i's were lower than required to yield minimum expected marginal value products for X_3 (labor) and X_4 (expenses), the differences, however, being small enough to fall within the respective 68.27 percent confidence intervals. The estimated b for X_2 (land) was higher than the b required to yield the minimum marginal value product that b being beyond its 68.27 percent confidence interval. The estimated b for X_5 (livestock and forage investment) was larger than the b required to yield the minimum marginal value product than b falling beyond the 95 percent confidence level. The b required to yield the minimum b for X_6 (machinery investment) fell within the 68.27 percent confidence limit for the estimated b_6. Standard errors of the regression coefficients are influenced by the size of the sample, the range in the observations of the independent variables and the intercorrelations existing among the independent variables. These effects may best be seen by examining the following equation:[8]

$$b_{13.24} = \sqrt{\frac{\bar{S}^2_{1.234}}{\sigma_3^2(1-R^2_{3.24})n}}$$

where σ_3^2 = the variance in X_3; n = size of sample, and $R^2_{3.24}$ = the percent of variance in X_3 explained by X_2 and X_4 combined. It may be seen that as the variance in X_3 increases and/or the size of the sample increases, the denominator is increased resulting in a smaller standard error. Conversly as $R^2_{3.24}$ increases the denominator decreases resulting in a larger standard error. The reliability of regression coefficients is reduced by the relatively high intercorrelations previously noted to exist among some of the independent variables. Such influences are accounted for in the standard errors of the b's. With a given amount of variance for the dependent variable, random overestimation of one of the regression coefficients is associated with underestimation of one or more of the other regression coefficients. Thus, when "outside" evidence indicates that one regression coefficient is high or low, a "system of biases" is likely to exist in the set of estimates. Such biases are, of course, reflected in the marginal value products estimated from the b_i's. It was to avoid such biases that range and lack of intercorrelation was sought in selecting the sample of farms and systematic checks were

---

[8] Ezekiel, op. cit., p. 502.

employed to insure the greatest amount of range and the least amount of intercorrelation feasible.

Despite this care, coefficients of multiple intercorrelation when computed were found to be high, that is:

$$R^2_{2.3456} = .6128 \qquad R_{2.3456} = .7828$$
$$R^2_{3.2456} = .5940 \qquad R_{3.2456} = .7707$$
$$R^2_{4.2356} = .6581 \qquad R_{4.2356} = .8112$$
$$R^2_{5.2346} = .6848 \qquad R_{5.2346} = .8275$$
$$R^2_{6.2345} = .7203 \qquad R_{6.2345} = .8487$$

Examination of the multiple correlations reveals that X_6, X_5 and X_4 were most highly correlated with the other independent variables indicating the possibility of compensating random errors in the estimated regression coefficients. The R's do not indicate, however, in which of the regression coefficients the likely errors exist. This is so because the R's indicate the intercorrelation existing between the respective X_i and the other independent X_i's combined but not with which of the other individual variables it is most highly correlated. To indicate this, the simple correlations were computed. These were found to be:

$$r_{23} = .6087 \qquad r_{24} = .7429 \qquad r_{25} = .6620 \qquad r_{26} = .6925$$
$$r_{34} = .6495 \qquad r_{35} = .7191 \qquad r_{36} = .7163$$
$$r_{45} = .6770 \qquad r_{46} = .7339$$
$$r_{56} = .7877$$

It may be seen by examining the simple correlation coefficients that X_5 and X_6 were highly correlated. Lesser degrees of correlation existed between X_2 and X_4, between X_6 and X_4, between X_3 and X_5 and between X_3

and X_6. Thus, the estimated b_i's for the above pairs of variables may contain "systems" of errors. In any of the above pairs then, one of the regression coefficients may be higher and the other lower than the true regression coefficients and consequently influence the marginal value products in the same way.

Examination of the estimated marginal value products for the different input categories in the light of outside information gives an indication of the probable direction of these errors. Labor, for instance, was measured in months, no attempt being made to differentiate labor resources with respect to quality or efficiency. It would appear reasonable that a more adequate method of handling this problem might produce a higher marginal value product for labor. In addition, several small farms which reported twelve months or more of labor employed, probably were actually using only some fraction of the reported amount. Thus, some "outside" evidence exists to support the conclusion that the b_i for labor and hence, the marginal value product of labor is underestimated. It could be underestimated by one half in view of the confidence interval for the regression coefficient for labor. However, the possibility that the last month of labor employed (often family labor) is actually earning a low marginal value product, should not be overlooked as much low quality labor is inefficiently used on Central Michigan farms.

Actual returns realized from non-tillable pasture land and farm wood lots were attributed to tillable acres of land due to the method of measuring land in tillable acres. This method of measurement may have had an upward influence on the estimated marginal value product of land (X_2).

The estimated marginal value product for expenses was believed to be too low as a minimum return of one dollar would be expected from the expenditure of one dollar. To aid in discovering discrepancies in methods of handling the data and the existence of unusual circumstances, the unexplained residuals in gross income were computed for each of the 33 farms included in the study.[9] The square root of the sum of the squared deviations was found to be 2,490 dollars. The data for farms having an unexplained residual large in relation to this figure were then examined. Numerous items were discovered which may account in part for certain of the large unexplained residuals and which may have influenced some of the estimated marginal value products.

For instance, on one farm which reported an actual gross income substantially higher than the expected gross income, it was found that eighteen percent of the reported gross income was from custom work and the sale of sunflower seed. Neither of these were common sources of substantial amounts of income on the other farms included in the study. This situation, however, does not appear to have biased the estimates of any of the b_i's and corresponding estimated marginal value product.

---

[9] This was done by substituting the log of each input category for each farm into the logarithmic form of the Cobb-Douglas function and solving for log X_1. The antilog of log X_1 was then determined and subtracted from the reported actual gross income to determine the residual.

Still further, an offsetting situation arose on a farm having a lower than expected gross income. On examining data for this farm it was found that all productive livestock were sold during the year. Reported receipts from the sale of breeding stock were 1,500 dollars less than the value placed on the stock at the beginning of the year. Most of the stock was sold at times when seasonal price levels were low, thus accounting, in part at least, for the loss.

Unusual circumstances in the operation of some of the farms were believed to have introduced a downward bias in the marginal value product of the expense category (X_4). It was discovered, in reviewing the data for a farm which reported a gross income considerably less than that expected, that fairly substantial expenditures were made for crops which were almost a complete failure, this would, of course, have a downward influence on the estimated marginal value product of expenses. The influence of this situation on the marginal value product of expenses, however, was not believed great as the farm was rather small.

In another instance, the farm found to have the greatest difference between actual and expected gross income was in the process of carrying out a fairly large expansion program in 1952. The dairy herd was enlarged substantially, necessitating feed expenditures of more than 6,100 dollars much of which was for the purchase of roughage. The returns from this type of expenditure were believed to be very low due to the high cost of handling and transporting roughage feeds. The usual practice is to raise all of the necessary roughage on the farm and purchase only the necessary high protein supplements. It was further found that due to the expanded dairy herd, expenditures amounting to more than 2,000 dollars were made for fertilizer, the major portion of which was used in establishing new permanent forage stands. Part of the amount used in establishing new permanent forage stands apparently should have been handled as an additional investment in forage and livestock rather than as an expense. As this farm had high expenses it furnishes considerable "outside" information for suspecting that the b for expenses and hence the marginal value product of expenses is biased downward.

On the basis of information discussed above, and in view of the intercorrelation present among the variables, it appears probable that the regression coefficient for tillable acres of land (X_2) is high with compensating underestimation of the regression coefficients for labor (X_3) and cash operating expenditures (X_4). In proposing a reorganization for farms, the possibility of such errors must be taken into account. That is, the estimated marginal value product for each input category should not necessarily be equated with the estimated minimum return when the estimates are "suspect."

As one further attempt to establish the significance of the marginal value product estimates, members[10] of the Farm Management staff at Michigan State College were asked to recommend a reorganization of the "usual" farm for the study. Their recommendations were essentially

---

[10] John Doneth, Warren Vincent, James Nielson, L. H. Brown and others.

the same as those logically based on the estimated marginal value products. Further, when told the statistical results, they were (1) somewhat skeptical of the low marginal value products for labor and expenses, (2) somewhat surprised at the high marginal value product for land and (3) skeptical of the high marginal value product for forage and livestock investments until made aware of (a) the high rate of depreciation on these assets and (b) the fact that the marginal value product has to cover depreciation. More confidence was placed in this sort of verification than in the statistical tests of significance. Concerning tests of significance, Wold states;[11] " . . . . . the conclusion is that in regression analysis of non-experimental data the formal tests of significance, however refined, carry little weight as compared with the non-formal and non-quantitative significance that is embodied in results derived from independent sources, provided these results support one another and form an organic whole."

Reorganization of Farms on the Basis of the Estimates

The ultimate objective of this study was to provide additional reference points to enhance judgement concerning the organization of a farm and to serve as guides in proposing possible alternative methods of organization.

The limitations of the study discussed above must be kept in mind and care used in applying the results. The estimated regression coefficients were believed reliable enough, however, to warrant their use in

---

11 Wold, op. cit., p. 58.

estimating marginal value products and gross income for different combinations of inputs.

As a preliminary to proposed reorganizations and general recommendations, consideration is first given to the effect on gross income and marginal value products of increasing one input category showing a high rate of return. The effects of increasing the livestock and forage investment from the usual amount of 7,126 dollars to 14,000 dollars in combination with the usual quantities of the other input categories are shown in Table III.

TABLE III

CHANGES IN MVP'S FOR THE "USUAL" ORGANIZATION RESULTING FROM INCREASING THE LIVESTOCK-FORAGE INVESTMENT FROM 7,126 DOLLARS TO 14,000 DOLLARS

Input Category		Quantity of Inputs	Original MVP (dollars)	New MVP (dollars)
X_2	Land	130 Acres	16.56	22.42
X_3	Labor	14 Months	30.19	40.86
X_4	Expenses	$ 3,348	.76	1.03
X_5	Livestock and Forage	14,000	.64	.442
X_6	Machinery	6,803	.19	.255

All of the marginal value products are increased by the expansion in livestock-forage investment with the exception of that for the livestock-forage investment (X_5). Estimated gross income was found to increase from 10,202 dollars to 13,809 dollars, this increase being due not only to the increase in revenue from livestock and forage but

also to the resultant increased marginal productivities of the other input categories. The effects of increasing livestock and forage investments illustrates the two-fold effect of the law of diminishing returns.

The impact of changed quantities of other inputs on the marginal value productivity of an input (labor) having low returns is illustrated in Figure 5. It is easily seen that as months of labor are increased, the marginal value product of labor falls rather rapidly at first, then less rapidly as the amount of labor employed increases. Figure 5 also shows that the marginal value product of labor is shifted upward as high-earning supporting inputs are increased. It is also apparent that livestock and forage which have a higher earning power relative to marginal cost than land bring about the greatest increase in the marginal value product of labor.

The results of increasing two input categories simultaneously are shown in Figure 6. Points A, B, C, and D represent successive trial quantities used in expanding livestock and forage and machinery investment categories, combined in proportions near optimum, given the other input categories in the usual quantities. This combination was expanded until the marginal value products for the inputs being expanded fell to a point reasonably near appropriate minimum expected returns, and not beyond the range of data used in estimating the equations. The marginal value products and gross income for each trial point were

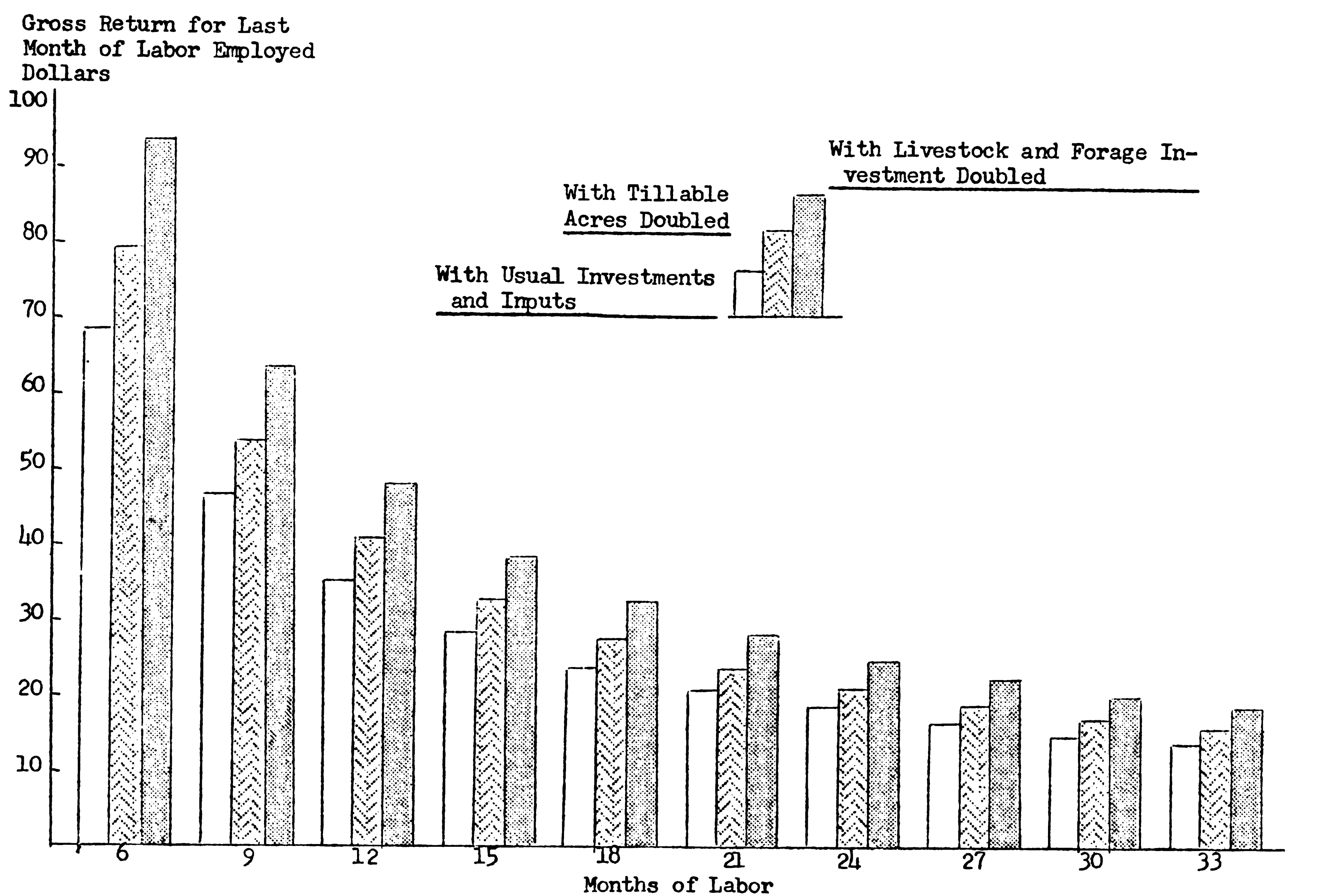


Figure 5. The Effects of Doubling Tillable Acres and Livestock and Forage Investment on the Marginal Value Productivity of Labor

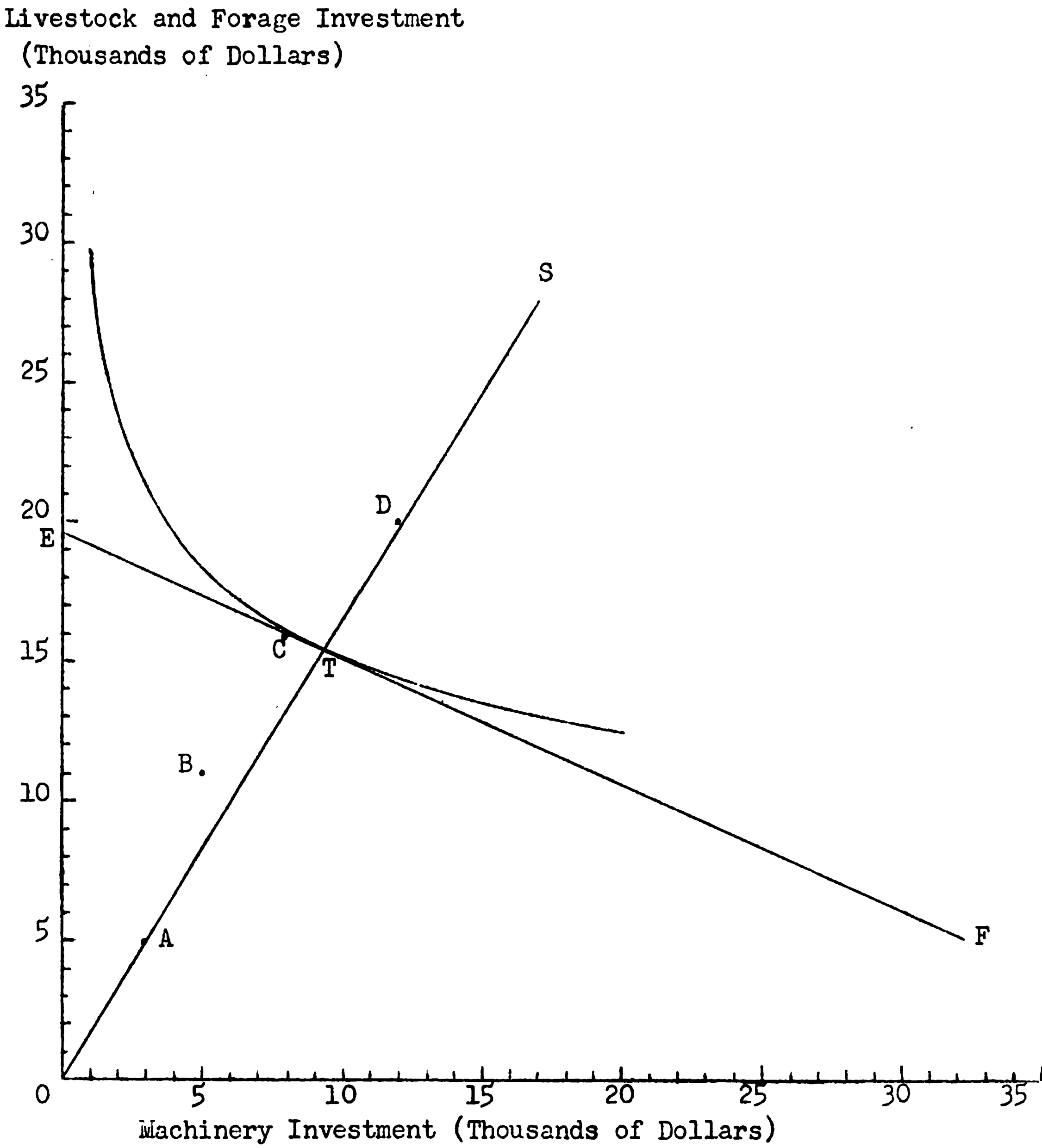


Figure 6. Trial Combinations of Machinery and Livestock - Forage Investments (Other Input Categories in the Usual Quantities) with Selected Iso-Cost and Iso-Value Product Curves and Expansion Line Superimposed.

computed to be:

Trial Point	MVP Livestock and Forage Investment	MVP Machinery Investment	Gross Income
A	.70	.32	$ 7,853
B	.48	.30	11,923
C	.42	.23	14,962
D	.39	.18	17,400

That these quantities are not exactly optimal for the stated situation is seen by inspecting the iso-value product curve of 15,000 dollars in relation to an iso-cost curve, based on a 45 percent reservation price for livestock and forage investments and a 20 percent reservation price for machinery investments. These were computed after the computations were made for each of the trial points. The iso-cost curve (EF) which is tangent to the iso-value product curve at point T represents an annual cost of 8,775 dollars based on a minimum expected return of forty-five cents per dollar of livestock and forage investment, and twenty cents per dollar invested in machinery. The scale line (OS) crosses through point T. At this point, the optimum proportions of the varied inputs, given other input categories in the usual quantities, are approximately 15,375 dollars invested in forage and livestock and 9,300 dollars worth of machinery investments. The annual cost of using these quantities are approximately 6,919 dollars for livestock and forage investments at 45 percent and 1,860 dollars for machinery investments at 20 percent.

After exploring the effects of increasing one or more of the input categories while holding others constant, a reorganization was developed. Though the estimated marginal factor costs are not equated with minimum expected returns for all input categories, it is evident that the reorganization represents combinations nearer the actual optimum than existed with the usual organization. The probable downward bias in the estimated marginal value products for labor and expenses and the upward bias in the estimated marginal product for land partially explain why marginal value products and marginal factor cost were not equated. The presence of non-significant increasing returns to scale in the estimating equation is another reason for not equating marginal value products and marginal factor cost based on minimum expected returns or reservation prices. The quantities of the input categories involved in the reorganization and the resultant estimated marginal value products are shown in Table IV.

TABLE IV

TENTATIVE OPTIMUM REORGANIZATION OF USUAL FARM, INGHAM COUNTY, 1952

Input Category	Quantity	MVP (dollars)
X_2 Land	200 Acres	15.14
X_3 Labor	12 Months	49.82
X_4 Expenses	$ 3,500	1.02
X_5 Livestock and Forage	12,000	.54
X_6 Machinery	7,500	.24

This combination of inputs results in an expected gross income of 14,350 dollars. The main emphasis was on increases in land and the livestock-forage investment category as these were experiencing returns which were apparently higher than necessary to cover the cost of using them.

It was estimated that this organization should allow for about twenty good dairy cows with enough feed raised on the farm to keep expenses near the figure indicated. The investment of 7,500 dollars in machinery should make it possible for one man adequately to handle this size of farm. With prices which existed in 1952, this would provide a net return sufficient to assure a standard of living satisfactory to most people.

The results which would be obtained by doubling all input categories in the reorganized plan are shown in Table V.

TABLE V

EFFECT ON MVP'S OF DOUBLING ALL INPUT CATEGORIES PROPOSED IN THE TENTATIVE OPTIMUM ORGANIZATION

Category	Quantity	MVP (dollars)
X_2 Land	400 Acres	15.68
X_3 Labor	24 Months	51.60
X_4 Expenses	$ 7,000	1.06
X_5 Livestock and Forage	24,000	.56
X_6 Machinery investment	13,000	.29

Expected gross income increased from 14,350 dollars to 29,726 dollars which was more than double. This, of course, was due to increasing returns to scale indicated in the data, and was further reflected in increased marginal value products for all input categories. As it was previously concluded that the data do not substantiate the hypothesis of increasing returns to scale, the matter of increasing farm size will not be examined further.

The usual organization was not believed to be extremely maladjusted, the main desirable adjustments indicated being (1) care in handling cash expenses, (2) reduced use of labor and (3) moderate expansion of acreage and livestock-forage investments.

To illustrate the other uses for the results of this type of analysis, a poorly adjusted individual farm in the sample was selected and a tentative reorganization proposed. The marginal value products for this farm business as organized in 1952 were computed as were the marginal value products resulting from the proposed reorganization. These are shown in Table VI.

TABLE VI

EXISTING AND A PROPOSED ORGANIZATION FOR A FARM STUDIED IN INGHAM COUNTY, 1952

Input Category		Existing Organization		Proposed Organization	
		Quantity	MVP	Quantity	MVP
X_2	Land	237 Acres	$ 9.43	237 Acres	$16.53
X_3	Labor	18 Months	24.50	15 Months	51.55
X_4	Expenses	$3,340	.79	$ 5,000	.92
X_5	Livestock and Forage	6,510	.73	15,000	.55
X_6	Machinery	3,940	.34	9,000	.26

The gross income for this farm was reported to be 10,030 dollars in 1952. The expected gross income as computed by the estimating equation was very near this figure being 10,585 dollars. As a result of increasing all input categories with the exception of tillable acres, expected gross income increased to 18,560 dollars. Comparison of the marginal value products before and after reorganization reveals that those for land, labor and expense categories were increased and those for livestock and forage investment and machinery investment were decreased. Again the two-fold effect of the operation of the law of diminishing returns is illustrated. Land was held constant, labor reduced, and expenses only slightly increased, while machinery and livestock-forage investments were greatly increased. The reduction in labor would not interfere with the employment of family labor on this farm as three months of hired labor were used in 1952.

Still another use for the results of this study can be illustrated as follows. Four high income farms were selected for comparisons as regards their organization. These comparisons are presented in Table VII.

Farm A had thirty-one good dairy cows with feeder hogs as a minor livestock enterprise. Livestock, machinery and crop expenses were all high contributing to the high total expense figure and resulting in the low marginal value productivity of that input category. The high earning power of livestock and forage on this farm indicates the desirability of expanding this phase of the business. This procedure along with more care in making expenditures and a reduction in labor used would be expected to increase the net return and the other marginal value productivities still further.

TABLE VII

COMPARISON OF ORGANIZATION, MARGINAL VALUE PRODUCTS AND GROSS INCOME, FOUR SELECTED FARMS, INGHAM COUNTY, 1952

Input	Farm A		Farm B		Farm C		Farm D	
	Quantity	MVP	Quantity	MVP	Quantity	MVP	Quantity	MVP
Land	358 A.	$19.76	170 A.	$19.99	240 A.	$21.90	323 A.	$17.01
Labor	32 Mo.	43.63	$12\frac{1}{2}$ Mo.	53.67	24 Mo.	43.24	25 Mo.	43.40
Expenses	$12,940	.65	$ 5,290	.76	$ 5,720	1.09	$ 5,570	1.17
Livestock-forage investment	19,350	.78	13,130	.55	23,040	.48	23,800	.49
Machinery investment	23,420	.18	7,750	.26	12,970	.24	23,480	.14
Gross Income	$33,511		$16,101		$24,906		$26,041	

Farm B was a smaller farm handled by the operator and occasional hired day labor. The barn arrangement was fairly good on this farm accounting for the ability of the operator to handle 25 dairy cows. These cows were not extra good cows. Artificial breeding was not being practiced on this farm. This probably accounts, in part, for the low capacity of the cows to produce. Increased investments in cows, particularly of better quality would be expected to increase the marginal value productivities of supporting investments and expenditures and net incomes.

Farm C had a large dairy herd (40 cows) of fairly good quality cows. Hogs were a minor livestock enterprise. The high marginal value productivity of the expense category on this farm was apparently due in part to an extremely good pasture program and, hence, relatively low expenditures on feed. The high return to land indicates the desirability of a moderate expansion in acreage. Accompanying this an expansion in the feeder hog enterprise (an expenditure item) would result in decreased marginal value productivities for these inputs, increase the marginal value products of other input and investment categories and increase the net income of the business.

Farm D was larger in acreage than the others relative to the livestock load. Very good hay and pasture were produced on this farm to feed twenty excellent dairy cows. This herd, in addition to high production in milk, produced purebred Holstein heifers, the sale of which contributed substantially to gross income. The hog enterprise on this farm was rather small. Good buildings were found on this farm with ample capacity to accommodate a considerable expansion in both the dairy and hog enterprises. Such an expansion would increase the low marginal value productivities of labor and machinery. The low return to machinery reflected a large machinery investment of 23,400 dollars which might profitably be reduced both absolutely and relatively (by expanding other inputs).

This brief discussion of possible ways individual farm organizations might be improved with the results of Cobb-Douglas analyses deals only with the more obvious maladjustments but serves to illustrate the possibilities which might profitably be explored in more detail.

CHAPTER VI

CONCLUSIONS

Given the price and weather conditions which existed for Ingham County farms of the type studied in 1952, the following statements can be made:

1. The estimated marginal value productivity of land on the Ingham County farms studied was found to be higher in 1952 than the return estimated to be necessary to cover the cost of using the input, this conclusion holding despite indications that the analysis somewhat over-estimates the marginal value productivity of land. This indicates that many farms can profitably expand use of this input and probably accounts for past and continued expansion in size of commercial farms.

2. Labor was not used efficiently on Ingham County farms in 1952. Although the estimated marginal value product of labor was probably lower than that actually existing on farms similar to those studied, returns are still believed to be lower than necessary to cover common wage rates paid to hired labor. Indications are that attention should be given to increasing labor efficiency by (1) using less of it relative to other inputs, (2) improving the technology of labor use, that is, through the use of farm work simplification and (3) increasing the absolute quantities of such supporting investments and expenditures as livestock-forage, land and machinery.

3. Cash operating expenditures were too high on Ingham County farms in 1952 as indicated by the low return found for this input category. This conclusion holds even though some basis exists for believing that the estimated marginal value product for expenses is lower than actually existed in 1952 on farms similar to those studied. Among the farmers appearing to be in most trouble in this respect, purchased feed made up the main expense item. A review of sample farms indicated that those which were producing ample amounts of high quality roughage were experiencing higher returns for this input category. Other research indicates that high quality roughage combined with high quality cows can reduce feed expenses and at the same time help increase the earning power of productive cash expenses.

4. Investments in livestock and forage were the most productive of the input categories studied on Ingham County farms in 1952. This indicates the need to further expand investments in these productive factors on most dairy farms under 1952 price and weather conditions. Examination of the data for sample farms indicated that those on which ample quantities of high quality roughage were produced and fed to high quality dairy cows were (1) experiencing high returns for labor and expense categories, and (2) reporting gross incomes sufficient to insure a very satisfactory standard of living.

5. This study indicated that the "usual" Ingham County farm studied was using machinery in about the right proportion relative to other supporting investments and expenditures. In view of the indicated need to expand the size of the "usual" farm and to increase

investments in livestock and forage, machinery should also be expanded in about the same proportion. Due to the low returns experienced by labor, machinery should be carefully selected to assure maximum labor efficiency.

6. No positive marginal value products for farm buildings on the "usual" Ingham County farm were indicated for 1952. The large amount of buildings on many farms apparently is due to the expansion in the size of farms. In a great many instances two or more small farms have been combined into one operating unit. Apparently the disposal value of the existing buildings is so low that they are left standing. Only a small fraction of their capacity is used in most cases. A review of the farms studied indicated that good barn arrangement is important. Those farms having barns arranged so as to allow higher labor efficiency were able to handle a greater amount of livestock and forage relative to quantities of other input categories and consequently the marginal value productivity of labor was increased.

APPENDIX A

SUPPLEMENTARY TABLES

TABLE VIII

REPLACEMENT COSTS USED IN COMPUTING ANIMAL UNITS OF BUILDINGS

Unit	Replacement cost per unit (dollars)
Dairy Cow (Including calves and hay)	403.00
Dairy Heifers and Steers	103.50
Bull	403.00
Sow and Litter (Individual housing)	85.00
Sow and Litter (Central farrowing house, two litters per year)	100.75
Boar	75.00
Feeder Hog	26.73
Hen	5.36
Broiler	1.78
Ewe or Ram	39.10
Feeder Lamb	30.60
Bushel of Ear Corn	.47
Bushel of Small Grain	.50
Milk House (Per cow)	35.28
Ton of Silage	10.83

TABLE IX

SUMMARY OF EMPIRICAL DATA GATHERED FROM THIRTY-THREE INGHAM COUNTY FARMS, 1952

Farm Number	Land (X_2) (Tillable Acres)	Labor (X_3) (Months)	Expenses (X_4) (Dollars)	Livestock-Forage Investment (X_5) (Dollars)	Machinery Investment (X_6) (Dollars)	Buildings (X_7) (Animal Units)	Gross Income (X_1) (Dollars)
1	120	13	2,770	8,830	3,650	38	7,520
* 3	98	12	3,430	15,180	11,580	45	14,140
4	185	16	3,700	12,160	9,000	54	15,880
5	323	25	5,570	23,800	23,480	61	28,210
6	358	32	12,940	19,350	23,420	80	35,480
7	155	24	2,760	7,860	11,300	42	8,860
8	183	30	5,540	19,080	13,100	63	27,600
9	157	7.5	2,780	5,720	4,130	29	5,960
10	147	14	2,600	10,690	5,900	46	14,900
11	237	18	3,340	6,510	3,940	41	10,030
12	100	12	1,410	4,340	7,620	38	6,320
13	170	12.5	5,290	13,130	7,750	58	15,120
*15	300	7.5	4,450	6,180	8,780	61	13,970
16	240	24	5,720	23,040	12,970	74	23,450
17	210	24	6,460	14,270	14,250	58	20,000
18	108	14.5	2,410	9,980	7,810	39	11,280
19	37	5	1,620	2,190	2,660	17	3,380
20	200	14	3,230	2,240	7,220	47	4,280
21	215	10	2,820	5,250	7,370	38	11,650
22	130	13.5	3,930	8,000	9,210	34	14,620
23	100	13	2,430	7,490	5,860	30	8,610
24	170	18	6,670	9,180	6,580	41	16,500
25	209	32	11,540	29,020	20,920	75	26,370
26	126	14.5	2,380	11,560	8,040	29	16,050
27	180	14	4,290	3,560	3,230	45	9,420
28	84	13.5	2,550	5,200	6,110	30	6,020
29	133	12.5	4,020	3,150	5,110	26	9,340
30	74.5	14	2,780	8,100	6,830	24	8,330
31	58	12	1,050	3,290	2,350	14	3,850
32	63	11.5	1,760	4,210	1,920	27	4,790
33	40	8	2,300	1,790	3,270	13	3,890
34	63	7	3,040	3,380	4,010	18	4,250
35	42	12	1,830	1,430	3,940	13	3,740

*Farms number 2 and 14 omitted due to inaccurate data.

APPENDIX B

COMPUTATIONS OF MARGINAL VALUE PRODUCTS

Computations of Marginal Value Products

Input Category		Quantity, Usual Organization	Regression Coefficient
X_2	Land	130.03 acres	.211072
X_3	Labor	14.08 months	.041663
X_4	Expenses	$3,348	.250010
X_5	Livestock-forage Investment	7,126	.448209
X_6	Machinery investment	6,803	.125561

The general formula used in computing the marginal value product is:

$$MVP_{X_i} = \frac{b_i(EX_1)}{X_i}$$

$$MVP_{X_2} = \frac{.211072(10202)}{130.03} = \$16.56$$

$$MVP_{X_3} = \frac{.041663(10202)}{14.08} = 30.19$$

$$MVP_{X_4} = \frac{.250010(10202)}{3348.} = .76$$

$$MVP_{X_5} = \frac{.448209(10202)}{7126.} = .64$$

$$MVP_{X_6} = \frac{.125561(10202)}{6803.} = .19$$

APPENDIX C

QUESTIONNAIRE USED IN PERSONAL INTERVIEWS

Farm No. ________

SIZE OF FARM

Total Acres	________	Owned	________	Rented	________
Tillable Acres	________	Owned	________	Rented	________
Woodlot Acres	________				

LABOR: MONTHS ON FARM

Operator	________	months
Family	________	months
Hired	________	months

GROSS INCOME

Date	Source	Quantity	Price	Amount Received
	Livestock and livestock products sold:		$	$
	Milk			
	Other dairy products			
	Eggs			
	Cattle			
	Hogs			
	Sheep			
	Poultry			
	Other livestock			
	Other livestock income (wool, breeding fees, etc.)			
	Crops sold:			
	Wheat			
	Oats			
	Corn			
	Sugar beets			
	Hay			
	Seed			
	Other			
	Custom work or machinery rented			
	Land and pasture rent			
	Other income form farm sources (excl. PMA)			

TOTAL CASH INCOME ________

GROSS INCOME (CONT'D)

VALUE OF FAMILY LIVING FURNISHED BY FARM

Farm Product	Amount	Price	Total Value
Milk		$	$
Butter			
Eggs (doz.)			
Poultry (lbs. or number)			
Beef			
Pork			
Mutton			
Fruit			
Vegetables			
Wood			
Other			

Total Value of Family Living Furnished by Farm $______

Total Cash Income ______

Livestock Inventory Increase or Decrease (From p. 7) ______

Feed & Seed Inventory Increase or Decrease (From p. 6) ______

TOTAL GROSS INCOME $______

FERTILIZER AND LIME

Kind	Use	Amount	Price	Cost
			$	$

Residual from fertilizer applied to annual crops, cover crops, small grain, old pastures and meadows.

							Residual Value
N, Total lbs.	______	x ___% =	______	x ___¢ =			$______
P_2O_5, Total lbs.	______	x ___% =	______	x ___¢ =			______
K_2O, Total lbs.	______	x ___% =	______	x ___¢ =			______
				TOTAL RESIDUAL VALUE			$______

Total cost of fertilizer from which residual is computed $______

Minus residual value ______

CURRENT FERTILIZER COST ______

. . . .

Residual fertilizer value $______

Total lime cost ______

Total cost of fertilizer applied to grasses, legumes, and other perennials seeded during year. ______

TOTAL FERTILIZER INVESTMENT $______

SEED AND PLANTS

Perennial seed and plants (Grasses, legumes, fruit)				Annual seed and plants (Corn, small grain, beets, cover crops, garden etc.		
Kind	lbs. seed	Acres seeded	Cost or value	Kind	Amount	Cost or value
Total						

(Carry total to perennial plant inventory) (Carry total to other expenses)

Beginning Inventory of Perennial Plants

Hay and pasture					Fruit			
Kind	Acres	Age and condition	Value per acre	Total value	Kind	Acres	Value per acre	Total value
			$	$			$	$

Total beg. value of perennials

Perennials Destroyed During Year

Kind	Acres	Value/acre	Date	Total value	Proportionate credit
		$		$	$
Total					

Total beginning value of perennials
- Minus proportionate credit of perennials destroyed
- Plus machinery hired for land reclamation
- Plus cost or value of perennial seed purchased & used
- Plus total fertilizer investment

Total investment

OTHER EXPENSES

Item	Quantity	Cost
Custom work or machinery hired		$
Gas and oil for farm use (less refund)		
Livestock expense:		
Feed		
Spray		
Veterinary and medicine		
Breeding fees		
Feeders purchased:		
Cattle		
Hogs		
Lambs		
Baby chicks purchased		
Automobile operation (farm share)		
Electricity (farm share)		
Telephone (farm share)		
Supplies (baling wire, sacks, strainer pads, etc.)		

Beginning inventory of feeder animals ______

Beginning inventory of broilers ______

Annual seed and plants purchased ______

Perennials destroyed during year (value) ______

Other expenses ______

Total expenses ______

FEED AND SEED INVENTORY

Kind	Beginning inventory Quantity	Beginning inventory Value	Ending inventory Quantity	Ending inventory Value
		$		$
Grain				
Corn				
Oats				
Wheat				
Hay				
Straw				
Commercial feeds				
Annual seed				
Perennial grass & legume seed				
Total				

Inventory increase $ ________

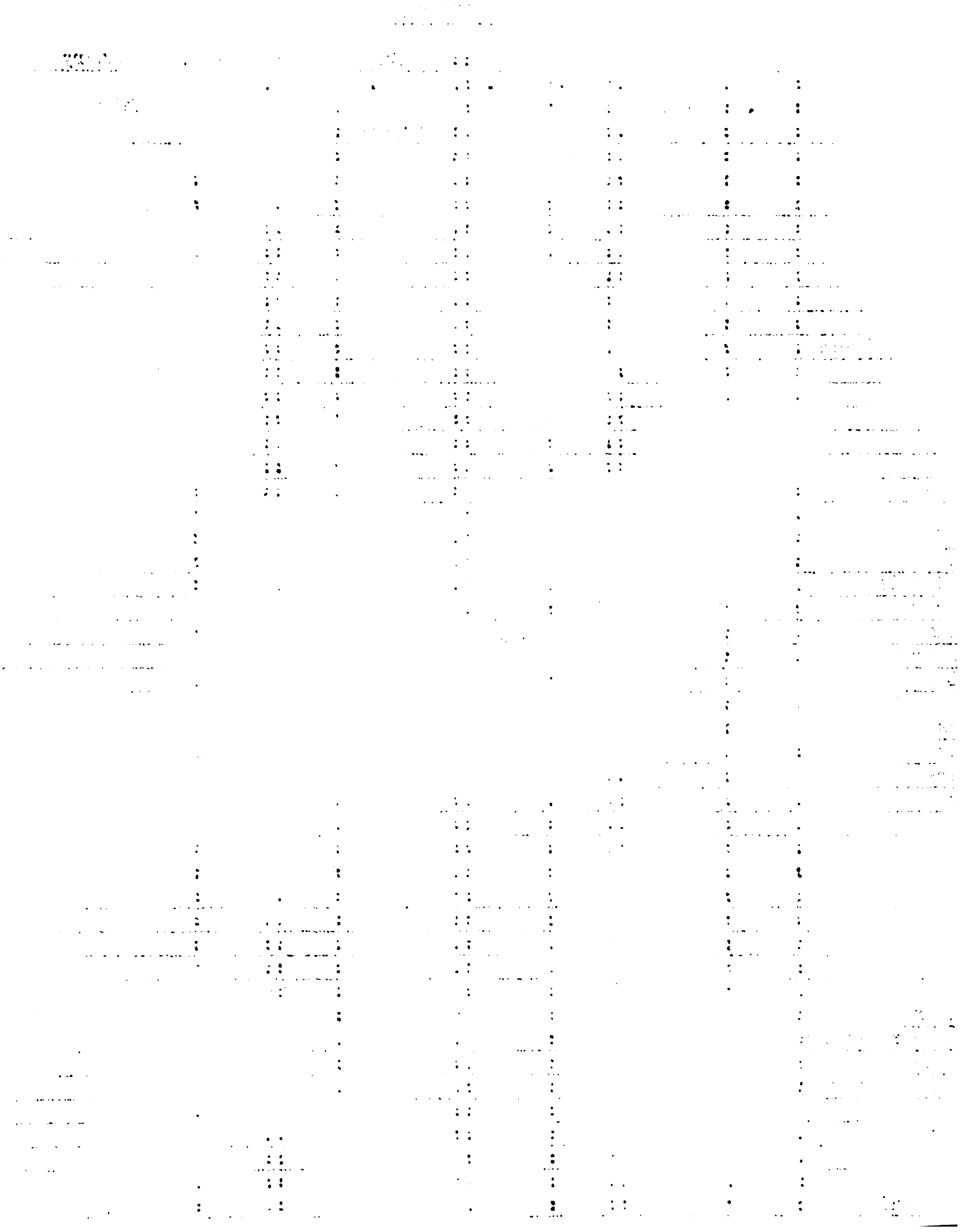
Inventory decrease $ ________

LIVESTOCK INVENTORY

Kind	Beg. inventory: No.	Beg. inventory: Value	Add: No. born	Add: No. bought	Subtract: No. sold and butchered	Subtract: No. died	End. inventory: No.	End. inventory: Value
Dairy								
Cows								
Bred heifers								
Unbred heifers								
Calves								
Bulls								
Beef								
Cows								
Bred heifers								
Unbred heifers								
Bulls								
Feeders								
Calves								
Hogs								
Sows								
Boars								
Pigs								
Feeders								
Sheep								
Ewes								
Rams								
Lambs								
Feeders								
Poultry								
Hens & roosters								
Broilers								
Other poultry								
Other								
Total								

Beginning inventory:
- Breeding stock ________
- Feeders ________
- Broilers ________

Ending inventory: (total) ________
- Breeding stock
  - Value of purchases ________
  - Beginning inventory ________
- Increase or decrease ________



Livestock Investment (Dollars)

Breeding Stock Bought During Year				Breeding Stock Sold During Year			
Date	What bought	Cost	Prop. cost	Date	What sold	Rc'vd.	Prop. credit

Total ________ Total ________

Beginning Inventory (Breeding Stock) ________
Plus Total Proportionate Cost ________
____
Minus Proportionate Credit ________
Total Breeding Livestock Investment ________

[illegible]

MACHINERY AND EQUIPMENT INVESTMENT
(Inventory beginning of year)

Item	Number	Value
Tractor and outfit		
Machinery & equipment not included in tractor outfit		
Truck		
Trailers & wagons		
Plows		
Harrows (spring tooth)(spike tooth)		
Disks		
Cultipacker or roller		
Cultivators		
Grain drill		
Seeder		
Seeder (hand)		
Corn planter		
Lime spreader		
Manure spreader		
Barn cleaner		
Binder		
Combine		
Field chopper		
Hay rake / mower		
Hay loader		
Hay forks or slings		
Mow dryer		
Corn picker		
Ensilage cutter (stationary)		
Feed grinders		
Elevator		
Blower		
Engines & motors		
Welder		
Milk cans		
Milk coolers		
Cream separator		
Milking machine		
Wash tank, can rack & other milk house equipment		
Water heater (milk house)		
Water pump		
General farm tools (forks, shovels, carpenter, shop, fence)		
Other		

Total $ ______

MACHINERY AND EQUIPMENT INVESTMENT (continued)

Purchases				Sales			
Date	Item	Total cost	Prop. add.	Date	Item	Total value	Prop. ded.
		$	$			$	$

Beginning inventory $ ______
Prop. add. ______
Prop. ded. ______

Total machinery investment $ ______

IMPROVEMENT INVESTMENT

Item and description	Capacity: Animal	Capacity: Hay	Capacity: Grain	Quality
Dairy barn				
Other barns				
Hog houses (farrowing, "A" type, etc.)				
Poultry houses (laying, broiler, brooder range shelters, etc.)				
Granary				
Corn crib				
Silo				
Other				

Drainage - Rods: 4 inch ______ 5 inch ______ 6 inch ______ ___inch ______

BIBLIOGRAPHY

Boulding, Kenneth E., Economic Analysis (Revised edition, New York: Harper and Brothers, 1948), pp. 671-612.

Bradford, Lawrence A. and Johnson, Glenn L., Farm Management Analysis (New York: John Wiley and Sons, Inc., 1953), pp. 113, cont. 129-131, 133, 144-145.

Broffenbrenner, Martin, "Production Functions: Cobb-Douglas, Interfirm, Intrafirm", Econometrica, XII, No. 1 (January, 1944), pp. 35-44.

Cobb, Charles W. and Douglas, Paul H., "A theory of Production", The American Economic Review (XVII Supplement, March, 1928), pp. 139-165.

Douglas, Paul H., Theory of Wages (New York: The Macmillan Company, 1934).

__________, "Are There Laws of Production?" The American Economic Review, XXXVIII, No. 1 (March, 1948), pp. 1-41.

Drake, Louis Schneider, "Problems and Results in the Use of Farm Account Records to Derive Cobb-Douglas Value Productivity Functions" (Unpublished Ph.D. Dissertation, Department of Agricultural Economics, Michigan State College, 1952).

Durand, David, "Some Thoughts on Marginal Productivity with Special Reference to Professor Douglas' Analysis", Journal of Political Economics, XLV (December, 1937), pp. 740-758.

Ezekiel, Mordecai, Methods of Correlation Analysis (Second edition, New York: John Wiley and Sons, Inc., 1949), pp. 360, cont. 455-485, 502, 508.

Fienup, Darrell F., Resource Productivity on Montana Dry-Land Crop Farms, Mimeograph Circular 66 (Bozeman: Montana State College Agricultural Experiment Station, 1952).

Heady, Earl O., Economics of Agricultural Production and Resource Use (New York: Prentice-Hall, Inc., 1952), pp. 146-147.

__________, "Production Functions from a Random Sample of Farms," Journal of Farm Economics XXVIII, No. 4 (November, 1946), pp. 989-1004.

Johnson, Glenn L., Sources of Income on Upland Marshall County Farms, Progress Report No. 1 (Lexington: Kentucky Agricultural Experiment Station, 1953).

__________, Sources of Income on Upland McCracken County Farms, Progress Report No. 2 (Lexington: Kentucky Agricultural Experiment Station, 1953).

Stigler, George J., The Theory of Price (New York: The Macmillan Company, 1947), pp. 113-125, cont. 244.

Tintner, Gerhard, "A Note on the Derivation of Production Functions from Farm Records", Econometrica, XII, No. 1 (January, 1944) pp. 26-34.

______________, and Brownlee, D. H., "Production Functions Derived from Farm Records," Journal of Farm Economics, XXVI, (August, 1944) pp. 566-571.

Toon, Thomas G., The Earning Power of Inputs, Investments and Expenditures on Upland Grayson County Farms During 1951, Progress Report No. 7 (Lexington: Kentucky Agricultural Experiment Station, 1953).

United States Department of Agriculture, Bureau of Chemistry and Soils, Soil Survey, Ingham County, Michigan (Washington: United States Printing Office, 1941).

Wilt, H. S., Unpublished data on estimated establishment costs for forage crops and small grains, Department of Agricultural Economics, Michigan State College

Wold, Herman, Demand Analysis (New York: John Wiley and Sons, Inc., 1953), pp. 56-59.

Wooley, John C., Farm Buildings (Second edition, New York: McGraw-Hill Book Company, Inc., 1946), pp. 21-23

Croxton, Frederick E. and Cowden, Dudley J., Applied General Statistics (New York: Prentice-Hall Inc., 1939), pp. 776-777.

United States Department of Agriculture, Bureau of Agricultural Economics, Agricultural Prices, Washington, D. C.

United States Department of Agriculture, Bureau of Agricultural Economics, The Farm Cost Situation, Washington, D. C.

Vary, Karl A., "Wage Rates Reported by Farmers" Michigan Farm Economics (East Lansing: Cooperative Extension Service, Department of Agricultural Economics, Michigan State College, August, 1953).