THE USE OF COBB-DOUGLAS ANALYSIS IN EVALUATING THE MICHIGAN TOWNSHIP EXTENSION PROGRAM

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THE USE OF COBB-DOUGLAS ANALYSIS IN EVALUATING THE MICHIGAN TOWNSHIP EXTENSION PROGRAM

By

Carl Eicher

AN ABSTRACT

Submitted to the College of Agriculture of Michigan State University in partial fulfillment of the requirements for the degree of

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ABSTRACT

The purpose of this study is to appraise the use of Cobb-Douglas analysis as a measure of economic efficiency for extension evaluation. In 1953, the Michigan Township Extension program was instituted in five townships. Each township has a full time township extension agent. Forty farms were selected in each of the five experimental townships and surveyed in 1953 for benchmark information. Control townships were selected to match the experimental townships. Control township farms were paired with the experimental township farms and on the basis of benchmark, intermediate, and terminal surveys, the changes in the experimental township will be compared to the control township changes. The changes occurring in the experimental township will be credited to the township agent while control township changes will be attributed to the county extension organization.

One of the major changes being measured in the experiment is economic efficiency. Economic efficiency is an instrumental value concerned with profit maximization of the firm. There are many available methods for measuring economic efficiency. The traditional farm management technique and Cobb-Douglas analysis are being used in the township experiment. Since Cobb-Douglas analysis has not been used in extension evaluation it will serve a dual purpose in the township program evaluation by providing estimates of the changes of efficiency in the program and also by providing information to extension administrators and evaluators on the cost, reliability, and value of using this method in extension evaluation.

The data for this study were taken from one of the five experimental townships and its matched control township. Thirty-three dairy farms in the experimental township and thirty-two dairy farms in the control township were used to fit Cobb-Douglas functions to establish the benchmark level of efficiency in these two townships for 1953.

Marginal value product estimates for land, labor, expenses, livestock-forage investment and machinery investment were derived for the two townships. Several statistical tests were used to determine if the level of efficiency for the two townships was the same for the benchmark year. On the basis of these tests, it was found that there was not a significantly different level of efficiency between the experimental and control township for 1953.

Cobb-Douglas analysis has several advantages which may be of interest to extension evaluators. It is a valid measure of efficiency. It measures the net returns to categories of inputs and investments in marginal terms. Also, it is a complete efficiency concept as it measures both input and output. The reliability of this method cannot be fully appraised until the completion of the five year experiment. On the basis of this study, three functions had to be fitted in the control township; thus the resulting control estimates are not clearly defined. Although more detailed information on the use of this method in extension evaluation will be available in 1958, it appears on the basis of using this method in measuring economic efficiency in two townships that is is one of the best measures of efficiency presently available.

It is felt that an extension evaluation program can be strengthened if both Cobb-Douglas and traditional farm management analyses are used to measure economic efficiency changes.

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CHAPTER I

INTRODUCTION

The Cooperative Extension Service has made important contributions in the development of American agriculture during the past forty-two years of its operation. One of the areas of extension work that has been receiving increased emphasis during the past decade is that of extension research. Research in extension is designed to measure the effectiveness of on-going extension programs, to experiment with new programs, and to point the way toward improved procedures for meeting the demands of modern agriculture.

One of the important factors facing extension evaluators is to determine what to measure, how to measure it, and to analyze the estimated cost and value of a specific type of measurement in order that a research program will yield the maximum useful information for extension administrators, specialists, and field workers. One of the factors to measure that confronts many extension evaluators is economic efficiency. Economic efficiency is an instrumental value that is concerned with profit maximization for the farm firm. Although economic efficiency is not an end in itself, it does provide an important avenue that farm families might use to improve their standards of living or to achieve broader goals and objectives in life.

Many extension evaluators have successfully used traditional farm management methods to measure the changes in economic efficiency which have occurred as a result of extension education. This thesis is designed to appraise and present the preliminary results of experimenting with a new method of measuring economic efficiency in extension evaluation by using a specific type of regression equation commonly known as Cobb-Douglas analysis. Cobb-Douglas analysis is based on static economic principles which measure returns to categories of inputs and investments in marginal terms. This type of analysis is being used along with traditional farm management methods to measure the changes in economic efficiency that occur as a result of the five-year township extension experiment that was established in five townships in Michigan during 1953. Various proven economic and sociological indices are being used to measure the changes resulting from the intensive township experiment. In addition, new approaches such as Cobb-Douglas analysis are being experimented with in order to determine their usefulness in extension evaluation. At the completion of the experiment in 1958, a complete report on the use of Cobb-Douglas analysis and other evaluation methods in the Michigan township program will be presented. This thesis will report the preliminary findings in using the Cobb-Douglas method to establish a benchmark level of economic efficiency for 1953 in one of the experimental and control townships in the Michigan township extension program.

This study uses the 1953 benchmark data for 33 dairy farms in one of the five experimental townships named Almont and 30 dairy farms in its matched control township of Burnside in order to fit Cobb-Douglas functions and outline the procedure followed in adapting this type of analysis for extension evaluation. Both the experimental and control townships used for this study are located in Lapeer County, Michigan, as shown in Figure I.

In order that the reader will understand some of the underlying factors about the nature of the Extension Service, extension evaluation, the Michigan township extension program, and the framework of this study, the remainder of this chapter will include developments of the Extension Service that led to the establishment of the township extension program, the objectives, operation, and evaluation of the Michigan township extension program, and the need for studying economic efficiency by extension evaluators.

The first objective of this study is to trace the historical and theoretical background of measuring economic efficiency. It will focus on empirical studies in agriculture and will discuss the procedure for extension evaluators to follow when using Cobb-Douglas type of analysis in measuring the changes in economic efficiency resulting from some phase of extension education. This objective will be presented in Chapter II.

The second objective is to measure marginal returns to categories of inputs and investments in Almont experimental township and its matched control township of Burnside for 1953, in order to compare the level of economic efficiency in the areas before the township program was started in late 1953. This will be covered in Chapter III.

The third objective is to use the benchmark data in the experimental and control townships to develop statistical tests which compare

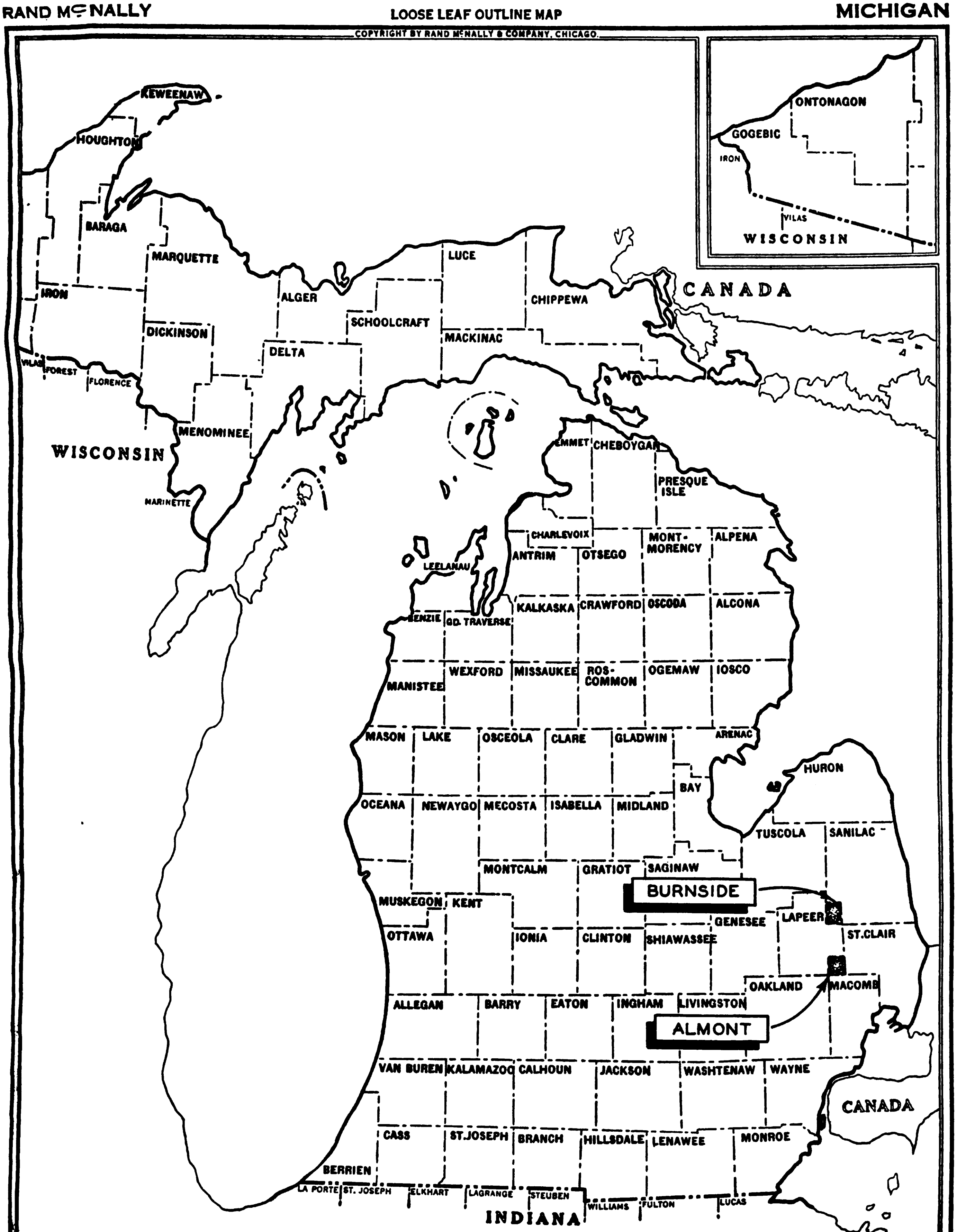

FIGURE 1. OUTLINE MAP OF MICHIGAN SHOWING ALMONT EXPERIMENTAL AND BURNSIDE CONTROL TOWNSHIPS FROM WHICH THE SAMPLES WERE DRAWN FOR THIS STUDY

0 5 10 20 30 40 50 60 MILES

MADE IN U.S.A. This Map is also available in size 17 x 22 156 OB 021

the levels of efficiency in the experimental and control areas for the base year of 1953. In addition, statistical tests and a procedure will be presented for evaluating the Cobb-Douglas results that will be obtained in the terminal survey in 1958 in order to compare and evaluate the changes in economic efficiency that occur as a result of the five-year intensive extension experiment.

The fourth objective is to recommend procedures to follow in collecting and processing the terminal survey data in 1958 so that accurate results can be obtained and compared to the original benchmark data. The third and fourth objectives will be discussed in Chapter IV.

The fifth and final objective of this study is to appraise the use of the Cobb-Douglas analysis for extension evaluators on the basis of collecting the data, analyzing the benchmark results, and computing various statistical tests in the two townships used in this study. Although final recommendations on the use of Cobb-Douglas analysis cannot be made until the completion of the experiment in 1958, some of the basic questions as to the cost, interpretation, and other factors to consider about the use of this method will be presented. This objective will be covered in Chapter V.

The Cooperative Extension Service

The Land Grant College system and the United States Department of Agriculture were both authorized in 1862 to render educational and research aid to American agriculture. Various measures were used by both organizations to relay the results of agricultural research to farmers. The Department of Agriculture used demonstrations, such as the control of plant diseases, to reach farmers, while the land-grant colleges participated in the educational programs of established agricultural societies and of farmers' institutes.

In 1906 Smith County, Texas, provided county funds to contribute toward the salary of a "demonstrator" who conducted demonstrations on the standard farm crops, gardens, and pastures.[1] This idea spread to counties in Louisiana in 1907. County funds were contributed toward the salaries of demonstrators of the United States Department of Agriculture. These demonstrators pioneered the county agent system. In 1911 the United States Department of Agriculture made cooperative arrangements with the state agricultural colleges for the initiation and management of the county demonstration projects. In 1912 a total of 639 county agents were at work in the South.[2]

The desirability of coordinating the efforts of the United States Department of Agriculture and the land-grant colleges led to the passage of the Smith-Lever Act in 1914 which provided for the Cooperative Extension Service. The act provided for a cooperative agricultural extension program between the agricultural colleges and the United States Department of Agriculture. The major purpose of

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[1] Orville Kile, The Farm Bureau Through Three Decades, (Baltimore: The Waverly Press, 1948), p. 27.

[2] Ibid., p. 28.

cooperative extension work as stated in the Smith-Lever Act is:

> . . . to aid in diffusing among people of the United States useful and practical information on subjects relating to agriculture and home economics, and to encourage the application of the same.[3]

From a pioneering handful of extension agents in 1914 the Cooperative Extension Service has expanded to almost every county of the United States.

The magnitude of the present day Extension Service is revealed in the following statement by Luke Schruben:

> The extension program today is a $100,000,000 operation with a staff of over 13,000 agents. Ten years ago the total budget was $36,000,000 and there were slightly less than 10,000 employees.[4]

The primary function of the Cooperative Extension Service is to provide educational information to rural and urban families so that they may identify and better solve their own problems. It is well recognized that one of the major roadblocks in providing more on-the-farm assistance by extension agents is that the heavy work load of the agents does not permit close attention to the problems of the individual. Currently there are over 1,100 farm families and 1,700 rural families per county agricultural agent.[5]

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[3] Ibid., p. 35.

[4] Luke M. Schruben, "Implementing State Extension Research," Research in Extension, National Workshop Report, Federal Extension Service, (Washington: United States Department of Agriculture, 1955), p. 161.

[5] Luke M. Schruben, "New Developments in Extension Work," (Paper read at the New England Research Council Meeting, Burlington, Vermont, June 24-25, 1954), p. 2.

In a recent survey conducted by the Prairie Farmer many county agents reported an extremely heavy load of chores that prevented them from making on-the-farm visits. One agent in Indiana stated:

> With all the night meetings there is not time to plan your work. The only time I have to prepare my speeches is driving in the car to my meetings.[6]

To meet the challenge of providing more on-the-farm assistance, Congress appropriated funds in 1954 that made possible the employment of 1,000 new extension agents under the farm and home development program. This program, as viewed by Charles M. Ferguson, administrator of the Federal Extension Service, would provide one new extension agent for every three counties on a national basis.[7] This increase was designed to render more individual on-the-farm assistance in order for farm families to make full and efficient use of their resources. In 1954 fifteen extension agents were employed as farm and home development agents in Michigan.

To meet the challenge of providing scientific analysis of how the Extension Service can best maximize the returns for its 100 million dollar yearly investment, special funds have been made available to measure the effectiveness of on-going programs and to experiment with new programs. State extension services interested in extension research have an opportunity to request funds for special research projects by submitting a research proposal to the Federal Extension Service.

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[6] Paul C. Johnson, "Your County Agent," Prairie Farmer, CXXIII, (October 6, 1951), p. 2.

[7] Charles M. Ferguson, "The Unit Approach--What Does It Expect of County Agents," Better Farming Methods, XXVI, (December, 1954), p. 12.

In addition, state cooperative extension services have received marked budget increases during the past decade. This increase in total available funds permits more money to be channeled into extension research. At the present time each state extension service can use part of its budget for extension evaluation projects. In addition to federal and state funds that are available for extension research several states have received grants from foundations for research projects. During 1955 the Extension Services of Iowa, North Carolina, Washington and New York each received a grant from the Kellogg Foundation of Battle Creek, Michigan, for a five-year evaluation of their farm and home development program.

An example of the urgent request for extension evaluation is reported in a recent report of the Cooperative Extension Service in New York State:

> The extension agent had and still has, more demands on his time than he can meet in carrying on this program. The best he has been able to do, then, has been a somewhat superficial kind of evaluation in which there has been more concern about what has been done rather than the effects of what has been done.[8]

The Michigan Extension Service

The Extension Service in Michigan has also moved ahead in offering more assistance to farm families and to urban people through urban 4-H, home demonstration agents, and community development specialists

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[8] "The Evaluation of the Intensive County Extension Programs in New York State," (prepared by the Cooperative Extension Service of Cornell University, Ithaca, New York, 1955), p. 2.

during the past few years. There are now over 420 extension agents employed in 78 of the 83 counties of Michigan. While the number of extension agents in Michigan has increased, the increase has not kept pace with the increased demands for assistance made upon the staff. To be more specific, the Michigan situation is pinpointed in the following statement:

> For example in the southern half of Michigan today one county agent attempts to serve as many as 4300 farmers--obviously an impossible task. It is well recognized that the major limiting factor in the effectiveness of the Cooperative Extension Service is the work load assigned to our county agents.[9]

The Michigan Township Extension Program

In order to scientifically determine how a more intensive extension program could be carried out in Michigan a grant from the Kellogg Foundation in 1953 made funds available to the Cooperative Extension Service of Michigan State University in order to set up, operate, and evaluate an intensive extension experiment in five townships distributed geographically about the state for a five-year period, 1953-1958. Since the inception of the Extension Service forty-two years ago, the smallest area for servicing farmers has usually been the county while this new experiment focused on the township.

The program is supported on a cooperative basis with Michigan State University, the township involved, and the Kellogg Foundation

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[9] "Proposal to the Kellogg Foundation for an Experimental Intensive Extension Program in Five Townships in Michigan," (prepared by the Cooperative Extension Service, Michigan State College, East Lansing, Michigan, 1953), p. 2.

participating. The contribution of Michigan State University is in the form of 75 subject matter specialists in agriculture and social sciences who are available to focus attention on the special problems of the townships. The contribution of the township varies depending upon the financial resources available in each case. The average township participation was estimated to not exceed $2500 per year. During the first two years of the experiment, most farmers have given voluntary contributions ranging from five to one hundred dollars per individual. A few farmers have participated in the township program but have not donated any money.

The contribution of the Kellogg Foundation is in the form of a grant to the Cooperative Extension Service of Michigan State University, to cover the difference between the total budget for each township and the amount which the township could contribute. The grant also covers the budget for a program coordinator and program evaluation. The grant provides funds to cover the total cost of evaluating the experiment.

Program objectives. An important objective of the township experiment is to determine if the Extension Service could make productive use of more resources and secondly, to determine if farmers would support an intensified approach of rendering more on-the-farm assistance to farm families. The basic objectives of the experiment as stated in the proposal to the Kellogg Foundation were to:

1. Increase farm earnings
2. Speed up the rate of adoption of improved farm practices
3. Raise standards of living for farm families
4. Improve rural communities

5. Increase agricultural output
6. Gain information on
    a. Effective extension methods
    b. Organizational patterns and techniques
    c. Communication skills
    d. Community recreation.[10]

The objectives of the township program as viewed by the present Michigan Extension Director, Paul A. Miller, are:

1. To determine how far the Extension Service can go quickly by applying the best in agricultural research and technology to local farm problems.

2. To determine how extension work can be carried on differently and more effectively.

3. To determine what new methods of cooperative financing can be developed between all concerned using local, state, federal and foundation funds.[11]

For this experiment an experienced extension agent was assigned in each of the five townships to work closely with individual farm families in an attempt to bring all available local, state, and federal resources to play in solving on-the-farm problems both in the home and in the total farm business.

The five experimental townships are located in the following types of farming areas: 1) dairy, 2) dairy and general farming, 3) general farming, 4) cash crops, and 5) dairy, potatoes, and general farming. There are from 160 to 200 farms in each township compared to 400 to 800 farms per county in the northern part of the lower peninsula of Michigan and from 2,000 to 4,500 farms per county in southern Michigan.

[10] *Ibid.*, pp. 2-5.

[11] Statement by Paul A. Miller, Director of the Michigan Cooperative Extension Service, at a meeting of the state farm editors, Michigan State University, April 15, 1956.

One township program was started in July, 1953, while the remaining four were added during the period of August, 1953, through January, 1954.

<u>Operating the Experiment</u>. A project coordinator was selected to organize and direct the township program in the five localities and to coordinate the activities of the extension specialist staff who advise and assist the township agents. The township coordinator makes periodic visits to the five townships and arranges regular meetings for the agents to discuss administrative and operational procedures of the program. The project coordinator is a part of and is located with the rest of the state administrative staff of the Extension Service at Michigan State University.

The township agents were selected from the ranks of county agents and assistant county agents. Four of the original five township agents are still located in their same townships, while one agent has taken up full-time farming. The agents spent about their first six months getting acquainted in their respective areas and offered assistance on a voluntary basis to all interested farm families. The number of farm families actively participating in the township program ranges from 40 to 90 depending upon the area, the type of farming, and the intensity of assistance rendered by the agent.

The township farmers participating in this experiment have elected a board of directors in each of the five townships. The board of directors is responsible for guiding the township agent and advising the agent as to the best method of operating the program. Although the agents are not administratively responsible to their board of directors, they work closely with them and attempt to move forward on a sound platform of offering an intensive educational program so that farm families might better help themselves. In addition, the members of the board of directors solicit voluntary contributions from participating farmers in an attempt to raise the needed township share of the funds without involving the township agent.

The boards of directors of the five townships hold an annual meeting at Michigan State University to discuss the progress of the program during the past year and methods for doing a more effective job.

Subject matter support at the request of the township agent is received from all departments at Michigan State University in the form of specialists who visit the townships, discuss new methods with the township agent, and make farm calls with the township agent. In addition, special, detailed soil surveys have been completed in three townships and soil booklets have been distributed to each farmer. A farm management extension specialist on a half-time basis provides detailed economic information on budgeting, record keeping, and renders general assistance to each agent by making personal visits and also by making farm visits and analyzing farm business records.

Program Evaluation. A project evaluator was assigned in 1953 to measure the degree to which the objectives of the operating program were met during the five-year experimental period. The objectives of the evaluation research project are 1) to measure the extent to which the objectives of the operating township program are met, and 2) to provide interpretative or explanatory information.[12] The research is attempting to measure what has happened as a result of the program and why these changes were made.

In order to isolate the changes attributed to the township program, five control townships were selected to match the five experimental townships and thereby provide a basis of comparison of the intensive extension approach with the traditional county extension organization. The control townships were chosen by matching an area with an experimental township on the basis of:

1. Markets
2. Types of farming
3. Soil association
4. Ethnic background of the farm people
5. County extension programs
    a. History of cooperation with extension in the area
    b. Current extension programs
    c. Distance from the county extension office
    d. Availability of meeting places
6. Proximity to large cities.[13]

Control farms were selected within each control township and paired with farms in the experimental township on the basis of age of operator, labor force, total acres, tillable acres, number of cows, and machinery investment. The principal difference between the farmers in the experimental townships and those in the control townships is participation in the program. It is the effects of this participation that will be measured by various economic and sociological indices.

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[12] James Nielson, "Notes on the Research Design and Procedure for Evaluating the Township Extension Program," (Department of Agricultural Economics, Michigan State University, East Lansing, Michigan, 1956), p. 1.

[13] James Nielson, "Farm Planning--Township Style," (Paper read at the New England Research Council Meeting, Burlington, Vermont, June 24-25, 1954), p. 5.

An important element of the evaluation of the experiment was that measurements designed to ascertain changes were set up to be used before, during, and after the completion of the experiment. The "before" measurements provided benchmark data which can be compared to the data recorded in the experimental and control townships during and at the completion of the experiment in order that any changes as a result of the township program can be isolated and interpreted.

Forty farms in each of the five experimental townships and forty matching farms in each of the five control townships were surveyed by personal interview in 1954 to obtain basic information on the 1953 farm operation. A total of 400 farms were surveyed for the benchmark survey; 200 in the five experimental townships paired with 200 in the five control townships. Each sample was homogeneous by farm type within the township areas. The individual farm surveys provided benchmark data for the measurement of changes that might occur as a result of the program. The survey schedule included all the information for Cobb-Douglas analysis and all the information commonly collected in the farm account project plus a net worth statement.[14]

In order to determine the extent to which the objectives of the program are met, the following measurements are being used in the evaluation process:

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[14]*Ibid.*

Objective	Measurement to Be Used and Methods of Getting Information
1. Financial progress of the farm families	1. Farm earnings--deflated 2. Family earnings--deflated 3. Family net worth This information will be gathered by benchmark and terminal surveys.
2. Adoption of farm practices	Extent to which farmers have adopted selected practices as reported by a benchmark, terminal and two intermediate farm surveys.
3. Volume and efficiency of production	1. Gross income deflated by price 2. Traditional farm business analysis measures 3. Marginal returns to investments and other inputs (Cobb-Douglas analysis) This information will be gathered by benchmark and terminal surveys.
4. Shifts in patterns of land use	Changes in acreage of land used for various purposes and implications of these shifts as determined by soil survey, and intermediate and terminal surveys.
5. Farmer participation in the Township program	How many families participated in the program, extent of their involvement, as determined by monthly and annual reports, case studies and surveys.
6. Formal and informal participation of farm families	Kind and quality of participation of farm families in a limited number of activities as reported by case studies and surveys.
7. Decision-making processes used by farm families	Factors considered by farmers in making decisions and involvement of various family members in the decision-making process as reported by case studies and surveys.
8. Extension techniques and communication methods	Study of approaches and methods used in the township program as determined by township agents' reports and administrative agents' remarks.

9. Attitudes toward the program and related matters	Attitudes of the following people to be studied: 1. Farmers in the experimental areas 2. Farmers outside the experimental areas 3. Township agents 4. Administrative and supervisory personnel 5. County agents 6. Specialists Factor one will be studied by an intermediate and terminal survey. Factor two will be checked by a terminal survey of farmers in the control area. Factors three to six will be analyzed by consulting with all extension agents connected with the program.[15]

Economic Efficiency

The efficiency of production or objective number three in the above chart is an important concept that farm management extension workers have attempted to define, measure, and interpret for many years. Economic efficiency is defined as the best use of resources which will produce the maximum profit for a firm. Many subjective factors such as a farmer's decision to substitute leisure time for work on Sunday or maximizing family welfare instead of profit maximizing, make it difficult to develop a useful efficiency concept that will include all the subjective factors as well as maximizing profit. The intangible factors such as "living in the country" or "being my own boss" are factors that have been ignored in previous efficiency

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[15] James Nielson, "Notes on the Research Design and Procedure for Evaluating the Township Extension Program," op. cit., pp. 4-6.

studies because of the lack of knowledge in defining and measuring these factors. This study will proceed as previous studies did and use dollar income or the profit motive as the index of measuring efficiency in order that a suitable efficiency measure can be devised to measure the changes in efficiency as a result of an extension program.

Measuring Economic Efficiency

Measuring efficiency is of great importance to farmers, extension agents, researchers, and agricultural policy workers. Information on resource efficiency can be useful in guiding individual farmers into a more profitable allocation of their resources. A farmer wishing to maximize profits can find the optimum combination of resources to use by comparing the returns to the input categories to the cost of using these inputs. Economic efficiency studies can point the direction and the method of reaching an optimum efficiency pattern and hence a maximum profit position. Use of input-output information draws together all the resources into a single framework of the nature that farmers must consider when making decisions. Efficiency studies combined with budgeting can be used effectively by farm planners in advising farmers how to make necessary farm adjustments.

The importance of measuring economic efficiency from the standpoint of extension workers can be discussed under 1) use in extension education, and 2) evaluation of extension programs. Extension agents need refined efficiency data in order to advise farmers how to make the necessary farming adjustment in order that they might maximize profits. Efficiency studies for specific types of farming and for specific areas of the state are essential in budgeting and farm planning.

Extension evaluators are faced with the important assignment of evaluating the changes that farmers make as a result of extension education and to determine why these changes were made. One of the methods of scientifically determining the impact of a new extension approach or a more intensive extension program is to measure the changes in economic efficiency that occur as a result of the extension education. Since extension agents attempt to help farmers increase their efficiency in order to maximize profits it is important to evaluate the changes in efficiency that are brought about by extension agents.

One of the goals of our society is that of securing the maximum welfare for all members. If efficiency studies in agriculture indicate low returns in agriculture relative to manufacturing, this suggests that too many resources are being used in agriculture and too few in manufacturing. Since society as a whole benefits in economic progress and increasing efficiency is one of the methods of reaching that goal, it is important to consider efficiency from a policy standpoint. Also economic efficiency studies in agriculture indicating differences in resource productivity in different areas of the country provide scientific methods of suggesting shifts to be made in resources in order to achieve maximum production in a period of needed increase in agricultural output.

The need for measuring the changes in economic efficiency in the Michigan township extension program is important not only to extension agents but to researchers and to the farmers in these five township areas. It is the belief that reliable economic efficiency information on the farms in the experimental townships will measure the results of township agricultural agents attempting to speed up the educational assistance to a small group of farmers over a five year time period. The benchmark survey in 1953 established the basic efficiency conditions on the farms in the five experimental and five control townships. The terminal survey will report the changes in economic efficiency that have been brought about by the township agents in the five experimental townships and the regular county extension organizations in the five control townships.

Since one of the goals of extension education is to bring about changes in technology on American farms, and, thereby, increase the efficiency of production, one of the logical measures of an extension evaluation program should be in the area of measuring economic efficiency.

It is the belief of the writer that farm families are interested in profit maximization as an avenue for improved standards of living. The farmers goal for profit maximizing is successfully achieved if the farm firm is able to make efficient use of its resources. Although many farmers do not openly admit that they are participating in extension programs in order to become more efficient operators, their basic reasons for participating often hides this important area. In a survey of 28 farmers in one of the five experimental townships after the program had been in operation for two years the farmers answered the question "Why did you decide to participate in the program?" in the following manner--(multiple response):

Response	Frequency
To obtain information	7
To get help	7
General feeling that it would be worth-while; had confidence in the Extension Service	5
Thought it would benefit the township or someone else in the township	5
Other reasons	12
Total	36 [16]

While the farmers in this experimental township did not openly mention that they were interested in increasing their efficiency of operation, their request for more information is one of the first steps in the chain of decision making that leads to greater economic efficiency.

It is necessary to outline the essentials of a good measure of efficiency before a specific method or methods can be recommended. It must be remembered that agriculture like other areas of production is a highly complex process and that no measure of efficiency can

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16 James Nielson, How Have Farmers Accepted the Township Extension Program in Almont Township, Lapeer County?, Department of Agricultural Economics Publication 648, Michigan State University, East Lansing, Michigan, April, 1956, pp. 21-22.

accurately predict all of the factors involved in the production process. The essential characteristics of a good measure of efficiency are:

1. To provide valid results by revealing the efficiency of the firm, provide an optimum scale of efficiency, and provide a basis of comparing efficiency over a time period. Two conditions necessary to provide valid results are that both input and output are measured and the results are stated in marginal terms.

2. To provide reliable results if the measure is repeated in the same parent population or in different sections of the country by the same or different researchers.

The two methods of measuring economic efficiency in the township extension program are the traditional farm management approach and Cobb-Douglas analysis. These methods tend to complement each other and provide a good over-all measure of the changes in economic efficiency. The results of using Cobb-Douglas analysis in this study will provide information as to the advantages and shortcomings of this method in order that Cobb-Douglas analysis can be compared with the essential characteristics of a good measure of efficiency. This comparison will be made in Chapter IV.

A brief review of background of these two methods of measuring economic efficiency will be discussed in the following section.

Traditional farm management analysis. The traditional farm management approach of measuring economic efficiency has been developed during the past three decades. Various physical ratios developed to measure efficiency in average terms are man work units accomplished per man, crop yield index, and milk produced per cow. Financial ratios such as returns per $100 feed fed to various kinds of livestock, and gross income per man have been developed under this method. While these efficiency measures like many other "rules of thumb" all provide useful information they fail to provide a complete input-output concept. The traditional farm management approach for many years has centered around selecting samples of farms in specific types of farming areas and after the business record of these farms are analyzed the low, average, and high income farms are compared in order to arrive at recommendations for reorganizing these farms. Economic efficiency under this system was computed by several common measures of output such as comparing gross income per $100 expense. This is a good over-all measure of efficiency but it does not reveal whether or not specific categories of inputs such as the livestock or machinery investment were efficiently utilized during the year. Although gross income per $100 expense does not measure returns to specific categories of inputs it is still a valuable index to use in extension evaluation. This index is a good over-all indicator of efficiency that can be easily and accurately computed for a group of farms before and after an extension educational program.

The traditional methods also attempt to measure the efficiency of individual inputs such as labor, machinery, and feed expense. An example of measuring labor efficiency is reported in the Area 6 and 7 report for 48 dairy farmers in Michigan for 1953:

> Labor efficiency as measured by days of work per man was 15 percent higher on the large farms. If measured by gross income per man there was little difference. The days per man measures the labor efficiency, thus showing the relation between the amount of business on the farm and the labor supply.[17]

A productive man work unit represents the amount of productive work that will be done by a man working at average labor efficiency in a ten-hour day. The productive man work unit concept is an average rather than a marginal measure. The weakness of this approach is the difficulty in comparing individual farms with the average farms, because there are many variations in the amount of assets that each farm uses with its labor force. This type of analysis does not indicate how much the last month of labor earns, for it takes the total of all inputs used in the production process and tells whether the days of work accomplished per man is higher or lower than the different income groups of farms.

Marginal analysis. The principles of marginality are also used to measure economic efficiency. Since the maximum profits to a firm can be explained only in terms of marginal analysis it is important to outline the terminology and definitions of marginality. When a unit of input such as an acre of land is added to the production process, the resultant increase in total product is called marginal or additional returns. Marginal returns is the ratio of change in total product as related to the change in input. Maximum profit and hence economic

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[17] John Doneth, Farming Today, Areas 6 and 7, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan, 1954, pp. 9-24.

efficiency is achieved when the marginal productivity of inputs and investments is such that it is impossible to shift the resources to different alternatives without causing the total product to decrease. For example, if the returns for one acre of land planted to corn yielded more profit than if the same acre were planted to wheat, then economic efficiency has not been met because it is still possible to cause the total product to increase by planting the acre to corn. The condition of economic efficiency is not met until all resources have been shifted from one alternative to another, so that further reshuffling of resources will cause the total product to decrease.

Marginal analysis measures labor efficiency by providing an estimate of what effect the last unit of input or investment had on gross income for the year. For example, if the last month of labor used on a dairy farm returns $80 the farmer could match the cost of a month of labor with the return and be able to determine how efficient his labor was for the year. This method also allows comparison of labor efficiency on dairy farms in different sections of the state or in different sections of the country.

One of the more refined methods of deriving input-output data by using marginal analysis is an algebraic method known as Cobb-Douglas analysis.[18] Other algebraic functions capable of measuring

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

efficiency are the Spillman[19] function and the quadratic[20] function. When measuring the effects of a large number (four to six) of variables such as land, labor, or machinery on gross income the Cobb-Douglas function has several important advantages over the other algebraic methods. Some of these advantages were reported by Tintner:

> The Cobb-Douglas function gives immediately elasticities of the product with respect to the factors of production; this form of the production function permits the phenomenon of decreasing marginal returns to come into evidence without using too many degrees of freedom; and finally, if the errors in the data are small and normally distributed a logarithmic transformation of the variables will preserve the normality to a substantial degree.[21]

Cobb-Douglas analysis was selected for this study in order that basic questions facing extension evaluators such as the cost, reliability, computations and statistical tests employed can be analyzed in one of the experimental townships and its matching control township. The results of using this analysis on the two townships will provide insight into the use of Cobb-Douglas as a possible measure of economic efficiency by extension evaluators.

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[19] William J. Spillman, Exponential Yield Curves in Fertilizer Experiments, United States Department of Agriculture Technical Bulletin 318, (Washington: Government Printing Office, 1943).

[20] Mordecai Ezekiel, Methods of Correlation Analysis, (New York: John Wiley and Sons, 1930).

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

CHAPTER II

THEORETICAL BACKGROUND OF COBB-DOUGLAS ANALYSIS

Historical Development

Professor Paul H. Douglas,[1] of the University of Chicago pioneered production function analysis in 1928 by computing indices of labor and capital for American manufacturing firms.[2]

Charles W. Cobb, a mathematician at Amherst College, co-authored the study and helped Douglas develop a function $P = bL^k C^{1-k}$ that measured the relative effect of labor and capital upon productivity during the period 1899 to 1922.[3] The dependent variable (P) expresses the total production value of industry, (C) is the total fixed capital available for production, (L) is the labor supply available to the entire industry and b is a constant. The exponents k and 1-k are coefficients of elasticity for P with respect to the independent variables labor and capital.[4] Cobb and Douglas forced the exponents equal to one which indicated constant returns to scale. The production

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[1] Now U. S. Senator Douglas from Illinois.

[2] Douglas, op. cit.

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

[4] An elasticity of a particular independent variable is the percentage change in total product when the variable is increased by one percent.

function devised by Cobb and Douglas is linear in logarithmic form. The values of elasticities can be estimated by a modified[5] least squares type of regression analysis.

A modification of the original Cobb-Douglas equation was made by Durand in 1937.[6] Durand presented a broader function where $P = bL^kC^j$ so that the sum of the exponents need not equal one. This allows increasing or decreasing returns to scale to be reflected in the total product. The exponents k and j are the coefficients of elasticity of P with respect to labor (L) and capital (C) while b is a constant. The broader function is linear in logarithmic form and the values of b, k, and j can be estimated by the method of least squares.

Empirical Studies in Agriculture

Tintner pioneered production functions in agriculture by using Durand's modified regression equation to derive productivity estimates of various input categories for 609 Iowa farms for 1942.[7]

Tintner and Brownlee used detailed farm account records of 468 Iowa farms to derive estimates of earning power for categories of inputs and investments for the year 1939.[8]

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[5] Tintner, op. cit., p. 31.

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

[7] Tintner, op. cit., pp. 26-34.

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

Heady followed Tintner and Brownlee and fitted the function to data from a random sample of 738 Iowa farms for the calendar year 1939.[9]

Fiemup, at Montana State College, used a random sample of wheat farms to study resource productivity on Montana dry land crop farms for the year of 1950.[10]

Drake at Michigan used farm account records for the year of 1950 to gain estimates of the marginal productivity of inputs.[11]

In 1952, Johnson at the University of Kentucky, used a non-representative or "purposive sampling" technique to select 234 Western Kentucky farms for Cobb-Douglas analysis.[12] Purposive sampling is a refinement of Tintner's random sampling method and Drake's farm account sampling technique. It is a method of selecting sample farms that are not in scale line adjustment, thus reducing the intercorrelation among input categories and thereby increasing the reliability of the estimated regression coefficients.

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

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

[11] 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).

[12] 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, 1952.

Similar studies employing purposive sampling techniques have been completed by Toon[13] at Kentucky and Wagley[14] at Michigan.

Since then several modifications and additions to Cobb-Douglas production functions have been made at Michigan by Trant[15] and Carter.[16]

Production Functions

The production function or input-output relationship is expressed in the following generalized form[17] $Y = F(X_1, X_2, X_3, X_4, \ldots, X_n)$ where Y refers to the value of the output and X's refer to the inputs or quantities of the various resources used.

If all inputs are variable and can be increased in constant proportions, then the output increases in constant proportions as illustrated geometrically in Figure II.

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

14 Robert Vance Wagley, "Marginal Productivity of Investments and Expenditures, Selected Ingham County Farms, 1952," (Unpublished M. S. Thesis, Department of Agricultural Economics, Michigan State College, 1953).

15 Gerald Ion Trant, "A Technique of Adjusting Marginal Value Productivity Estimates for Changing Prices," (Unpublished M. S. Thesis, Department of Agricultural Economics, Michigan State College, 1954).

16 Harold O. Carter, "Modifications of the Cobb-Douglas Function to Destroy Constant Elasticity and Symmetry," (Unpublished M. S. Thesis, Department of Agricultural Economics, Michigan State University, 1955).

17 Richard G. D. Allen, Mathematical Analysis for Economists, (London: Macmillan and Co., 1947), pp. 284-291.

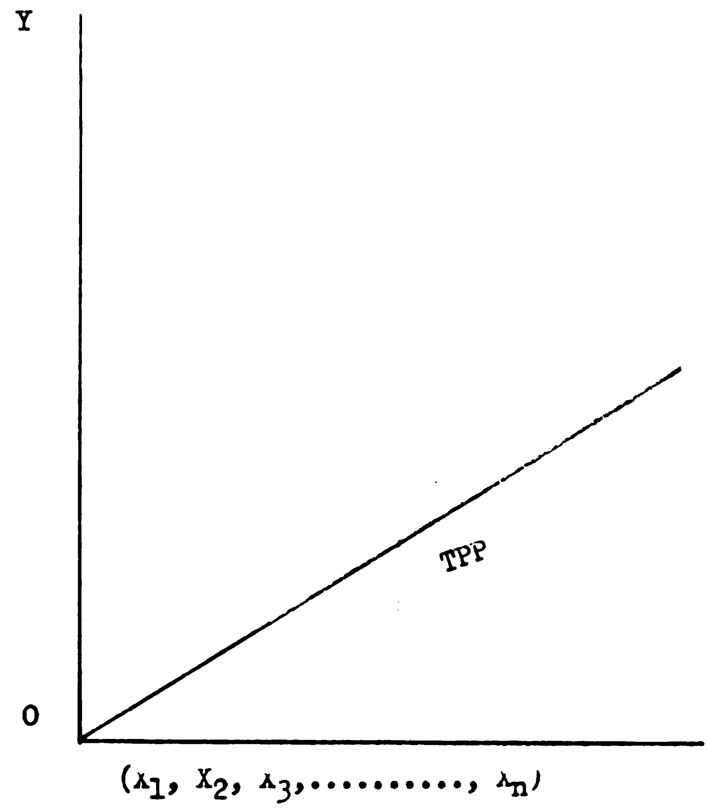

Figure II. Total Physical Product, All Inputs Variable and Increased in Constant Proportions.

When some inputs are held constant and others variable, the "law of diminishing returns"[18] or the "law of variable proportions" holds true. This relationship is stated as follows: as more units of variable inputs starting from zero are added to fixed inputs, the total physical product[19] increases at an increasing rate, then increases at a decreasing rate and then decreases.

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18 George J. Stigler, The Theory of Price, (New York: Macmillan Co., 1950), pp. 116f.

19 This relationship also holds true for the marginal and average physical product. See Sidney Weintraub, Price Theory, (New York: Pitman Publishing Co., 1949), pp. 78f.

The influence of fixed inputs is responsible for the occurrence of diminishing returns. For example the subfunction $Y = f(x_1 x_2 | x_3 \ldots, x_n)$ as illustrated geometrically in Figure III shows the effect of fixing $x_3 \ldots x_n$ while x_1 and x_2 are variable.

The production function is divided into three stages. The second stage as illustrated in Figure III is the only rational one to produce in if it pays to produce at all.[20]

The Cobb-Douglas function is capable of showing only one of the three stages of production at a time; therefore, since most farms are assumed to be operating in Stage II, purposive sampling is used to select farms that are operating in this stage.[21]

Value Productivity Functions

In order to locate the optimum amount of inputs to use in producing a product and also in order to determine the amount of a product to produce, the price of inputs and outputs as well as the physical relationships must be considered. The physical production relationships outlined in Figure III are multiplied by the price of the product in order to convert them into value productivity relationships. A value productivity function expresses the relationship between the value of the products produced and the inputs and investments used in producing

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[20] Stigler, op. cit., pp. 124-125.

[21] Lawrence A. Bradford and Glenn L. Johnson, Farm Management Analysis, (New York: John Wiley and Sons, Inc., 1953), p. 145.

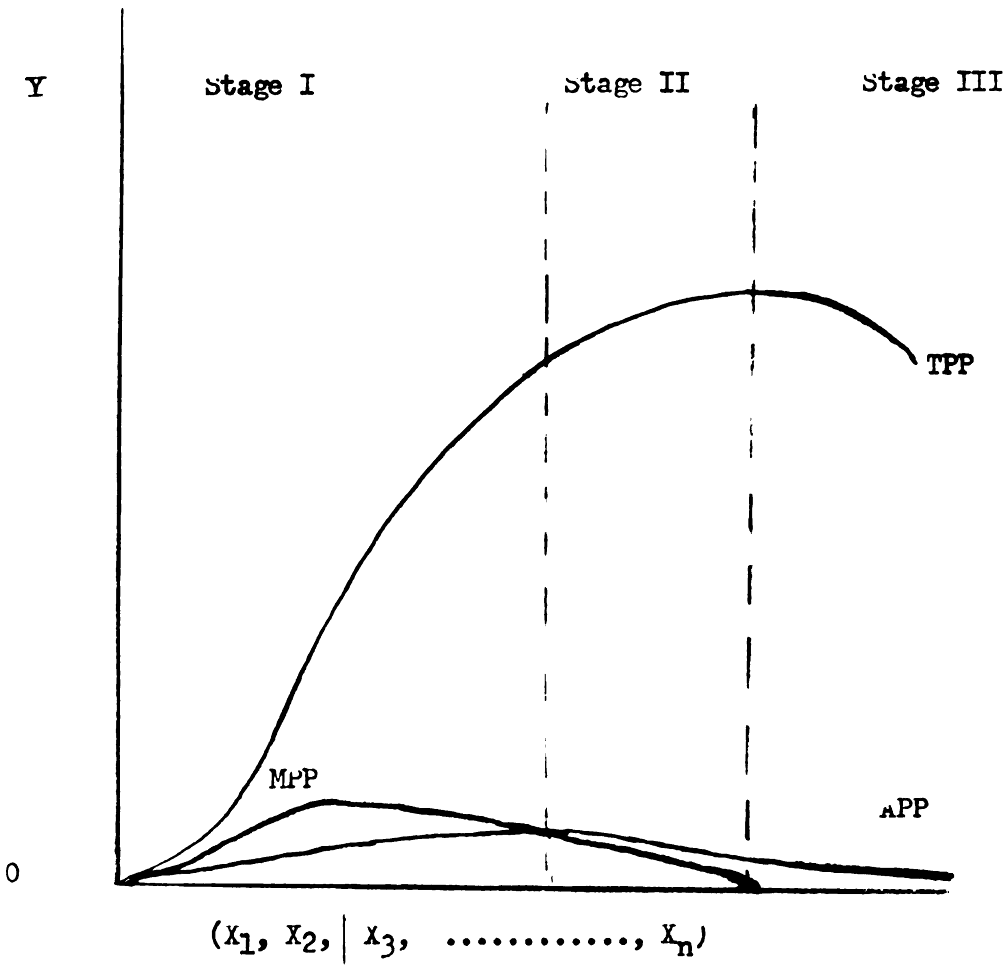

Figure III. Diagram Showing the Law of Diminishing Returns.

those products.[22] In Figure III the marginal physical product and the average physical product are multiplied by the price of the product (Y) and are thus converted into value productivity relationships. In Figure IV they are labeled, MVP, meaning marginal value product and AVP, meaning average value product. Since the total physical product is expressed in physical terms it is labeled TPP in Figure IV.

The optimum amount of an input to use in producing a product is demonstrated by the intersection of the price line labeled PX_1 with the MVP curve or at point C in Figure IV. At this point the MVP $=$ PX_1 which means that the value of the marginal product is equal to the cost of the last unit of input. Beyond C, the dollar returns derived by using another unit of input is less than the cost of the input. Use of less than C amount of X_1 would permit additional profits to be made by using the additional units of X_1 which would yield a dollar return in excess of their cost.[23]

In Figure IV the law of diminishing returns is reflected in the marginal and average value product and the total physical product as they start from zero and increase at an increasing rate, increase at a decreasing rate and then finally decrease. This phenomenon is caused by the fixed inputs, X_2 --- X_n. The law of diminishing returns also holds true when more than one variable input is used in the production process. This means that marginal returns to single variable inputs or to groups of inputs first increase, then decrease, and

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[22] Glenn L. Johnson, "The Cobb-Douglas Production Function with Special Reference to Fitting Value Productivity Functions for Farm Businesses," Tentative draft of a technical bulletin, Department of Agricultural Economics, Michigan State University, 1956, p. 3.

[23] Bradford and Johnson, op. cit., p. 119.

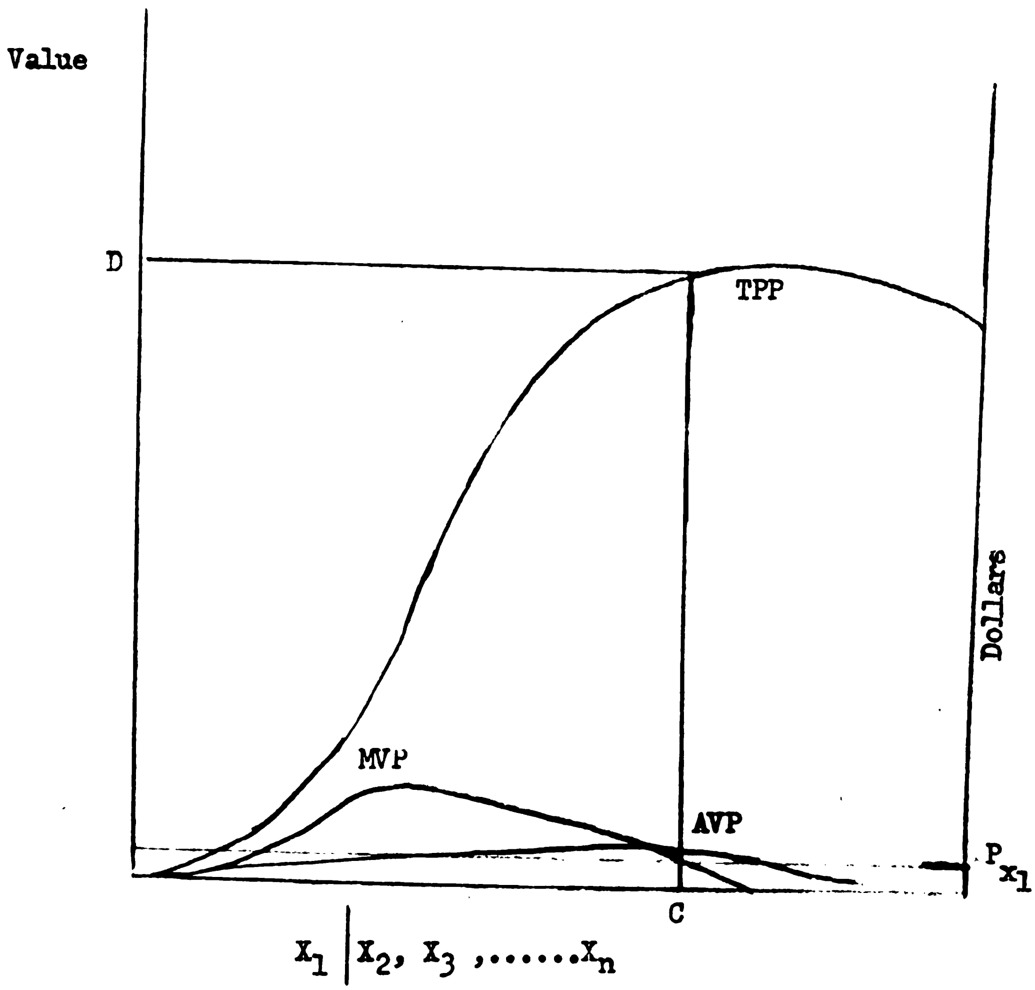

Figure IV. Diagram showing the relationship between the value of marginal product, total physical product, average value product and the price of the variable input. X_1 is variable and X_2 .... to X_n are fixed.

finally become negative. When more than one variable input is used in the production process, these inputs are properly used when the ratio of the cost of the input to the marginal product of the input is the same for all inputs used in the production process.

The amount of Y produced by C units of X_1 in Figure IV is found from the TPP curve at a point directly above C which is represented by D units of Y. The basic economic principle of matching added returns to added costs of producing these returns is used to determine an optimum amount of Y to produce.

The basic principles of marginal analysis formulate the framework for using algebraic functions such as the Cobb-Douglas function to provide estimates of the returns to categories of inputs. By using these estimates a manager can see what returns are being received for the inputs and investments used in the production process. He also is able to use these estimates to answer the basic question of how much Y to produce and how much of X_1 to X_n to use in producing that amount of Y.

Another important point to consider in using algebraic functions is that the basic law of diminishing returns holds true for all functions. The Cobb-Douglas function is capable of reflecting diminishing returns for any input or investment category.

An ideal value productivity function for an individual farm business reflects only the actual relationships between groups of inputs and investments and gross income.[24]

It is doubtful that any single algebraic function can accurately predict all of the actual relationships between groups of inputs and investments used in producing gross income. The Cobb-Douglas type of analysis used in this study to derive value productivity estimates is one of many possible algebraic methods for arriving at an estimate of a real value productivity function.

In practice the theoretical shortcomings of each algebraic function are multiplied by the practical shortcomings arising in the collection of data, grouping of inputs, and unexplained residuals resulting from uncontrollable variables. These factors cause the most precise method to fall short in reflecting accurately all the characteristics of the actual relationship between gross income and the groups of investments and expenses.

Cobb-Douglas Production Function

The first step in understanding how Cobb-Douglas value productivity estimates are used in farm business analysis is to present the characteristics of an ideally fitted Cobb-Douglas function.

The general form of a Cobb-Douglas function is $Y = aX_1^{b_1}, X_2^{b_2}, \ldots, X_n^{b_n}$ where Y is output, $X_1, \ldots, X_n$ are inputs, the "a" is a constant and $b_1 \ldots b_n$ are constants measuring the elasticity of Y with respect to the corresponding X_i.

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24 Johnson, "The Cobb-Douglas Production Function with Special Reference to Fitting Value Productivity Functions," *op. cit.*, p. 3.

The principle characteristics of an ideally fitted Cobb-Douglas function are outlined by Johnson as follows:[25]

(1) It is easy to estimate its constants by ordinary least-squares regression methods after a simple logarithmic transformation of the raw data.

(2) It can reflect a tendency in data toward diminishing positive, increasing positive, diminishing negative, and increasing negative marginal returns to individual groups of inputs and investments.

(3) It can reflect a tendency in data toward diminishing positive, increasing positive, diminishing negative and increasing negative marginal returns to the totality of groups of inputs and investments.

(4) The bi's are elasticities of gross income with respect to the corresponding inputs.

a. As elasticities are constant over all ranges of the Xi's, Cobb-Douglas functions display constant elasticity throughout. This means that, at best, the Cobb-Douglas function can approximate only a segment of the ideal production function.

b. The sum of all the bi's is the elasticity of gross income with respect to all measured inputs and investments. Thus, if $\sum$ bi's > 1 increasing returns, if $\sum$ bi's < 1 decreasing returns and if $\sum$ bi's $= 1$ constant returns to scale exist on the function.

(5) The marginal value productivity of an Xi, which is the increase in gross income resulting from an increase in the use of Xi with other resources held constant, can be computed from the following equation: $MVP_{Xi} = \frac{bi\ E(Y)}{Xi}$[26] where E(Y) is the expected gross income of the set of Xi's under consideration.

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[25] *Ibid.*, p. 5.

[26] $$MVP_{Xi} = \frac{Y}{Xi} = d(aX_1^{b_1} X_2^{b_2} \ldots X_n^{b_n}) = b_1 aX_1^{b-1} X_2^{b_2} \ldots X_n^{b_n} \quad ?$$

$$= \frac{b_1 aX_1^{b^1} . X_2^{b_2} \ldots X_n}{X_1}$$

$$= \frac{b_1 E(Y)}{X_1}$$

(6) Estimated $MVP_{Xi's}$ are useful in locating least cost combinations of inputs and investments and highest profit levels of operation; hence, they have great practical significance in indicating profitable reorganization of farms as a basis for both public and private policy.

Rules for Selecting Farms on the Same Production Function

Toon outlined five conditions that should be met before a group of farms can be assumed to be operating on the same production function:

1. All farms should be operating at the same level of technology.
2. All farms should be producing similar products.
3. Inputs within each category should be in optimum combination.
4. All farms should be using the same inputs.
5. All farms should be on the same inherent soil productivity.[27]

Grouping of inputs. Accurate grouping of inputs and investments into meaningful categories of expenses and investments is a prequisite for obtaining reliable survey results. Therefore, in designing the schedule, the following rules of thumb for grouping inputs are suggested by Glenn L. Johnson:

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 categories made up of complements (a) be measured in terms of units combined in the proper proportions (which are relatively unaffected by price relationships) and (b) be

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[27]Toon, op. cit., p. 20.

priced on an index basis with constant weights assigned to each complementary input.

4. That the categories of inputs be neither perfect complements nor 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.)[28]

Steps to Follow in Fitting a Cobb-Douglas Function to Agricultural Data

A detailed account of the general procedure to follow in setting up an input-output study, selecting the sample area, selecting the sample farms, designing the survey schedule, collecting the data, grouping the inputs, analyzing the data, fitting the function, statistical tests, and interpreting the results of the data will be presented in the following section.

Framework of Production Function Study

Production function studies or input-output studies as they are commonly called by farm management extension workers are used in agriculture to provide estimates of the earning power of categories of inputs and investments that are used to generate gross income. The general production function or input-output relationship illustrates how gross income of Y depends upon the inputs and investments. In the

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

following general function $Y = f(x_1 \ldots x_g) | (x_{g+1} \ldots X_n) + U$ the output Y is dependent upon three classifications of inputs and investments. The variable inputs $(x_1 \ldots x_g)$ are studied while fixed inputs designated $(x_{g+1} \ldots x_n)$ are held fixed by the research design and the unmeasurable and unstudied variables designated U are assumed to be randomly and normally distributed. Examples of studied variables are:

1. land
2. labor
3. livestock-forage investment
4. machinery investment
5. cash expenses

The fixed variables in an input-output study include some of the following factors:

1. type of farming
2. soil type
3. altitude
4. rainfall
5. technology employed
6. geographic location as it is associated with the growing season
7. all farms employing the same inputs
8. data are selected for only one year of operation

The unmeasured and unstudied variables that are assumed to be randomly and normally distributed in an input-output study include some of the following:

1. managerial ability
2. geographic variations in price, weather and technology
3. variation of productivity within soil types
4. institutional factors
5. asset control

The general framework of an input-output study is found in the function described above where the output depends upon studied variables, fixed variables, plus certain unmeasured and unstudied factors that are assumed to be randomly distributed in the sample area. In order to measure accurately the units of inputs that are used to create output during the farm year, a general sample design must be set up. First of all, it is important to know the theoretical nature of the function. This step is followed by analyzing the resources available for the study so that the intensity of the survey, the method of surveying, and number of farms surveyed can be determined. After selecting the sample area, the sample farms must be selected and surveyed. The data must be converted into logarithms and least squares regression analysis used to fit the function. The final step is to compute statistical tests for the fitted functions and to interpret the results of the study.

Research design. The first step that researchers may follow in setting up an input-output study is to state the problem, available funds, and outline the alternative methods available to solve the problem. In Michigan the cost of using Cobb-Douglas analysis to gather information on efficiency of production for an area has ranged from $ 900-1200 for a sample of 30-40 farms. This is approximately $30 per processed schedule, including the field interview and the statistical computations. The cost of Cobb-Douglas studies will be further explored in Chapter V. The studied variables usually include land, labor, cash expenses, livestock-forage investment, and machinery investment. The fixed variables will depend upon the area under study and the physical characteristics of the area that can be fixed and isolated by the researcher. For example, the ideal set-up for

handling fixed factors would be to obtain an area that has fixed patterns of soil, rainfall, type of farming, and so forth. It is realized that this is impossible; therefore, a researcher must include tolerance for the factors that he is attempting to fix. The unmeasured and unstudied factors must be carefully examined, because one of two major variations in these factors on a particular farm or on several farms can bias the results so that they are unusable. Another unstudied variable assumed to be randomly distributed is managerial ability. Since it is impossible to classify or to measure managerial ability, it is one of the variables that must be given subjective consideration by every interviewer.

Determining the sampling technique to employ. The three main sampling techniques used to collect data for input-output studies are: random sampling, farm account records, and the purposive sampling technique. Before any one of the three can be recommended the characteristics of each must be carefully examined.

The random sampling technique was used in the early Cobb-Douglas studies in agriculture whereby a number of farms (100-700) were selected to represent the universe or the complete data for the area. This method involves selecting a certain percentage of farms in an area without much regard for the range in the quantities of inputs used in the production process. For example, Tintner[29] used random sampling to select 609 farms and Heady[30] followed by using the same

[29] Tintner, op. cit.

[30] Heady, op. cit., pp. 989-1004.

procedure to select 738 farms. Minor restrictions such as limiting the farms to more than thirty acres in size can be used in a random sampling technique. The main limitation of this method is the cost of collecting the data. At $30 a schedule, a 700-schedule survey would cost approximately $21,000.

The farm account record system involves analyzing the data from a selected number of farm account records to derive productivity estimates. Johnson[31] discovered the lack of data on the livestock-forage and machinery investments was a major limitation of using farm account records. In addition, farm account record farms are usually well adjusted firms that are on a higher production function than the average farms in the area. The well adjusted factor causes high intercorrelations between the input categories and thereby causes high standard errors of the bi's. The purposive sampling technique used by Johnson[32] in Kentucky is a method whereby farms are selected with a wide range in the quantities and proportions of inputs. The wide range in the input categories reduces the intercorrelation between the input categories; thereby, reducing the standard errors of the regression coefficients. The equation[33] used to compute the standard error is:

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[31] Statement by Glenn L. Johnson, personal interview.

[32] Johnson, Sources of Income on Upland Marshall County Farms, op. cit.

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

$$b\ 13.23 = \sqrt{\frac{\bar{S}^2\ 1.24}{n\ \sigma_3^2\ (1-R^2\ 3.24)}}$$

where n = the size of the sample, σ_3^2 = the variance in X_3, R^2 3.24 = the percent of variance in X_3 explained by X_2 and X_4 combined.

The three factors that affect the size of the standard errors are: the size of the sample or n, the intercorrelations existing among independent variables or R^2 and the range in independent variables as measured by σX_i^2 or σ_3^2 in the above example. As the size of the sample or σX_i^2 increases or R^2 decreases the denominator increases and the standard error of the bi decreases. In order to reduce the σb_i, the researcher can either increase the n which involves an additional expenditure of funds for extra sampling, select farms that have a wide variation in the quantities of inputs and investments so that the R^2 or correlation between the inputs is decreased and thus the standard error of the bi will be reduced, or increase the range in the observation of the independent variables. Suppose the following information were available to a researcher: n = 40, R^2 = .9 and x^2 is 10. A purposive sampling plan which decreases R from .9 to .8 would decrease the standard error of bi as much as doubling the sample size n from 40 to 80.[34] At $30 a schedule, the saving for 40 records would be $1200. In addition to saving money by using purposive sampling to reduce the standard error of the bi's, this method also allows control

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[34] Johnson, "The Cobb-Douglas Production Function with Special Reference to Fitting Value Productivity Functions," op. cit., p. 20.

to be maintained over the variables which the researcher wishes to hold fixed. This means that instead of selecting farms from several counties and running the chance of having wide variations in factors such as soil type, rainfall, the researcher is able to maintain control over these factors when the sample area is restricted to a county size and purposive sampling is used.

Selecting the sample area. Since the Cobb-Douglas function can accurately predict returns for one type of farming, it is necessary to analyze the area picked for the study and to determine if a sample of 30 to 40 farms of a specific type of farming can be selected. The usual area for accurate results in the mid-west section of the country is from one to three counties with most cases falling in the one county limit. If a larger area than several counties is used for the sample area, it is difficult to maintain control over factors such as the type of soil, rainfall, and type of farming. It was found in one study in Michigan that increasing the size of the sample area from one to three counties caused sizable unexplained errors in the results so that the sample size was reduced to the original one-county area. Several suggested methods for selecting the sample area are to consult with the soil science department, county agricultural agents, visit farms in the area under consideration and to compare the crop yields and characteristics of the farms in the area by examining the census data and individual farm account records. Accurate sample areas cannot be mapped out in the office as it takes a thorough knowledge of the local situation before a balanced area can be selected.

Selecting the number of farms. If purposive sampling is used to select farms for fitting a Cobb-Douglas function, the minimum number of farms to be selected on the basis of this study for a township or county area would be 35, while the maximum would be around 45. This allows five to ten schedules that do not meet the requirements for soil type, percentage of gross income from one type of farming, or other accounting errors to be deleted from the sample. The minimum usuable schedules necessary to obtain a reliable Cobb-Douglas fit ranges from 25 to 35. The ideal method for selecting the farms is to plot the range of input data on a simple chart before each interview is taken. This method consists of asking a farmer the number of acres, and the months of labor, without getting involved in taking several hours time to take the interview and then being forced to delete it. For example, after finding a farm which produces more gross income from fruit than from its dairy enterprise, the farm could be by-passed.

Selecting the sample farms. The general criteria used to select farms for the type of farming requirement is to require that at least 50-60 percent of their gross income be derived from the type of farming under study. Minor deviations from the arbitrary standard can be made, but the more precisely the data are taken from a specific type of farming area, the more reliable the results will be. In addition, the farms should be on the same type of soil and should be using the same inputs in producing the products.

Designing the survey schedule. The schedule should provide an account of all factors used in production during the year and the resulting breakdown of the sources of income for the year. The detailed breakdown for the items to include in the survey schedule are discussed in Chapter III.

Data emmeration. Several helpful guides for collecting the data in the field include the following: record all data that is available from reliable record books or farm plans; back up several years with a farmer and draw a map of his farm so that he can recall the age of the forage stand or the amount of fertilizer that was applied during the year; include the entire share of the farm operation, as many tenant farmers keep records for their share of the business only; and finally carry a portable adding machine to check the totals of the schedules taken during the day so that any questionable point can be checked while the survey team is in the local area. About two hours per farm are required to collect the basic data for Cobb-Douglas analysis.

Analyzing the data. The first step in processing the schedules is to set up a set of instructions to follow so that all schedules will be handled in the same manner. This is especially helpful if clerical staff workers are analyzing the data. The values of forage stands, prices of products, yards of lime to tons and other such items should be clearly spelled out. It took about two to three weeks for a clerical worker to analyze the schedules and make the necessary computations for Cobb-Douglas analysis on thirty to forty schedules in each township of this study.

After each schedule is analyzed, it is suggested that the totals for each farm by input and investment category and gross income be recorded on a large table. This permits a quick comparison of one farm with another to detect any errors that were missed in the computations. The schedules are then re-examined and the ones that are incomplete or fail to meet certain sampling specifications are deleted from the sample. About 15 per cent of the schedules were deleted in this study.

Fitting technique. The general technique for fitting the function was taken from Ezekiel.[35] The first step in fitting the function is to convert all the inputs and investments for each farm into logarithms and then set the logarithms up into a table. The linear multiple intercorrelation procedure is used to fit the function. Cross multiplications or extensions are computed for each variable for each farm, the sums of which are the cross products. Check sums are used to check the accuracy of the extensions. The Doolittle[36] method is used to solve the normal equations for the b's and the c's. The c's are used to compute the standard errors of the regression coefficients (b's). The b's are then fitted into the estimating equation with the logarithms of the geometric means of the inputs and the equation is solved for the constant (log a). The antilog of (log a) is "a." The general steps to follow in carrying out a Cobb-Douglas function after the values of the regression coefficients (bi's) have been computed are shown in

[35] Ezekiel, op. cit., Appendix I.

[36] Ibid., p. 161.

the following case:

Input Category	Quantity of Inputs	bi's
X_2 Land	142.1	.289740
X_3 Labor	18.4	.160090
X_4 Cash expenses	$3,271	.284260
X_5 Livestock-forage	$7,227	.322018
X_6 Machinery	$6,073	.139422

Value of a = .424494
n = 30 farms

The general equation for fitting a Cobb-Douglas function that has one dependent and five independent variables is:

$$X_1 = aX_2^{b_2} \ldots X_3^{b_3} \ldots X_4^{b_4} \ldots X_5^{b_5} \ldots X_6^{b_6}$$

The meaning of each of the symbols in the equation will be explained. The a is a constant; $b^2 \ldots . b^6$ are referred to as regression coefficients, for they measure the amount of change in X_1 with a unit change in $X_2 \ldots X_6$. For example, the value of b_2 of .289740 indicates that a one percent increase in the amount of land used in the production process would cause a .289740 percentage increase in the gross income. The regression coefficients are also called elasticities. The $X_2 \ldots X_6$ are the geometric mean proportions of the inputs used in the production process. For example, the value of X_2 was 142.1 acres. This is the geometric mean average of the amount of land that was used on the 30 farms in this case. Gross income is designated X_1 in the above equation.

The next step is to convert the mean values of the input and investment categories, $X_2 \ldots X_6$, into logarithms. The logarithms of $X_2 \ldots X_6$, value of a, and $b_2 \ldots b_6$ are substituted in the equation in order to solve for X_1.

$$\text{Log } X_1 = .424494 + .289740\ (2.152576) + .160090\ (1.263663) + .284260\ (3.514655) + .322018\ (3.858956) + .139422\ (3.783425)$$

$\text{Log } X_1 = 4.019703$, the antilog of which is \$10,464.

This illustrates how the geometric mean proportions of 142.1 acres of land, 18.4 months of labor, \$3,271 of cash expenses, \$7,227 of livestock-forage investment and \$6,073 of machinery investment produced a gross income of \$10,464 on the 30 farms in this case.

The general statistical data for the function are expressed in the following section.

The multiple correlation coefficient (R) measures the relation of gross income with the independent variables such as $X_2 \ldots X_6$ in this case study. It does not tell anything about the relative importance of each independent variable, but it does give an indication of the over-all effect of the variable upon the gross income. If no errors were made and all variables were included in the multiple correlation, the multiple correlation would approach 1.0. A high coefficient of multiple determination such as .91 in this case study connotes a high degree of association between $X_2 \ldots X_6$ and X_1. In many cases this high coefficient might be caused by only one or two variables; so it is important to compute simple correlations of the independent variables. These will be presented in a later section in this chapter.

The coefficient of determination or R^2 indicates the percentage of variance in gross income that can be explained by the independent variables. In this case the value of R^2 was .84 which meant that 84 percent of the gross income is accounted for by the five independent variables. The remaining 16 percent is unexplained, as it might come from factors such as management, soil variation, weather variation and other factors that were not studied but were assumed to be randomly and normally distributed. It is important for a sample to be able to have a 70-90 percent of its gross income be explainable by the independent variables, as predictions for farm reorganization are of limited value if they are based on inputs that only partially explain gross income.

The standard error of estimate $\bar{S}$ of gross income indicates the closeness with which values of the dependent variable may be estimated from the independent variables. Small standard errors indicate low degrees of variability, whereas large standard errors reflect a large degree of variability within gross income. The standard error of .087934 for the logarithm of gross income of 4.019703, the antilog of which is $10,464, means that two-thirds of the time the gross income for the sample farms would fall within the range of $8,546 and $12,813. If the standard error were much higher in this study, the range of gross income for two-thirds of the farms might be from $5,000 to $15,000; thereby, causing the prediction of gross income on farms to be of limited value.

The standard error of estimate of the regression coefficients was discussed in this section on page 45.

Marginal value products. After the bi's, a, and X_1 are computed, these factors can be substituted into the general equation $MVP\ x_i = \frac{bi\ E(Y)}{xi}$ in order to determine the marginal value products of the five input and investment categories. The marginal value product refers to the net returns to the categories of inputs or investments. In the above equation the E(Y) is the expected gross income or \$10,464 that will be produced by the set of X_2 .. X_6. The bi in the equation refers to the regression coefficient or elasticity that is a constant for the X_i. The X_i refers to the geometric mean of the input or investment category. Both E(Y) and x_i are measured in natural numbers. For example the MVP of X_2 in this case will be computed. The value of X_2 = 142.1; the value of bi = .289700 and the E(Y) = \$10,464. Substituting these values in the above equation gives $MVP\ X_2 = \frac{.289740\ (\$10,464)}{142.1}$ or an MVP X_2 of \$21.33. This means that the marginal value product of the last acre of land applied to the production process would return \$21.33 above the cost of planting, harvesting that acre of land.

Marginal value product estimates are of value to farm managers, teachers, extension agents, extension researchers and credit agencies, for they provide estimates of the earning power of inputs like cash expenses and land for a specific area and a specific type of farming. The problems of budgeting are greatly simplified if information is available on marginal returns of the major categories of inputs and investments. For example the basic principles of expanding output until the marginal value product equals the marginal factor cost can easily be derived by comparing the estimated marginal value products with the costs (sometimes subjectively determined such as the minimum costs of depreciation, repairs and maintenance of farm machinery) of using that input or investment. If a manager requires a 20 per cent return on his machinery investment and finds the marginal value product of machinery investment yields a five to ten per cent return, the logical move is to decrease the amount of machinery for the present combination of inputs. If he finds that land and other inputs need to be expanded relative to the machinery investment it is possible to combine the present machinery investment with the expanded inputs so that a more profitable total reorganization will result. Using this method allows a farm operator to increase the returns to the machinery investment while at the same time the returns for the other inputs and investments are increased.

A sound decision as to how to best reorganize the farm operation can be made only after comparing the returns to all inputs individually but at the same time. For example, the returns to one input or investment might indicate a reduction in the use of that input would increase gross income while another input could be expanded to increase gross income. It is therefore necessary to consider the over-all effect of expanding or contracting the use of all inputs or investments rather than trying to reorganize the farm on the basis of changing the use of one input at a time.

A detailed discussion of the factors to consider in interpreting the results of Cobb-Douglas analysis as a measure of economic efficiency will be discussed in Chapter IV. The interpretation of the results for extension evaluation will be presented in Chapter V.

CHAPTER III

COLLECTION OF DATA AND FITTING THE FUNCTION

The data for this study were taken from thirty-eight dairy farms in Almont experimental township and forty dairy farms in Burnside control township in Lapeer County for the year of 1953. These areas were selected for study because they represent one of the five experimental and control townships in the township extension program in which the writer interviewed some of the farmers and is familiar with the dairy type of farming operation being carried on in both townships.

The Sample Townships

Almont experimental township is six miles square in size. It had 181 farms in 1953 of which 65 were dairy farms, twelve vegetable farms, six commercial orchard farms and the remaining 98 were engaged in general farming.[1] The township agent, located in the village of Almont, assists only the Almont township farmers interested in the township extension program.

The Burnside control township is located twelve miles north of Almont township and is six miles by nine miles in size. In 1953, there were 251 farms in Burnside township, the higher number of farms

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1 Albert Hall, "Monthly Report of Almont Township Extension Agent," (Cooperative Extension Service, Michigan State College, East Lansing, Michigan, 1953).

than in Almont township being partly attributed to the larger size of Burnside township.[2] Dairying is also the major enterprise of most farms in Burnside township. The farmers in Burnside control township receive assistance from the Lapeer County extension staff located in the village of Lapeer which is 24 miles southwest of the village of Burnside. Lapeer county extension agents serve about 3,000 farmers.

Ethnic Groups

The farmers of Almont and Burnside townships are primarily of West European origin.

Market Outlets

The principal fluid milk outlet for both townships is located at Imlay City which is 13 miles north of the village of Almont and nine miles south of the village of Burnside. The county seat of Lapeer, an excellent farm shopping center, is fifteen miles northwest of Almont and twenty-four miles southwest of Burnside.

Soil Type

The soils for Almont experimental township are level to rolling that have been developed from glacial till. They are primarily Miami and Conover soil type, relatively high in fertility and are suitable

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[2] Statement by James Nielsen, personal interview.

for row crops such as beans, and corn.[3]

The soils of Burnside control township are of two major classifications: The northern two-thirds of the township has a nearly level, fertile type of soil that is high in organic matter. The southern third of the township is composed of hilly, well-drained soils that have a low fertility. For this reason the sample of farms surveyed in Burnside township was taken from the northern two-thirds of the township, for the soil association closely matched the soil of Almont township. Two farms located in the sandy section of Burnside township were included in the control sample but were later removed from this study, as they were on a lower production function than the remaining farms in Almont experimental and Burnside control township.

The soil types in Almont and Burnside township have approximately the same inherent characteristics and the same level of productivity with the exception of the sandy southern third of Burnside township.[4]

Climatic Factors

Although a wide variation in the length of growing season exists in many areas of Michigan, the length of growing season for both the experimental and control townships is from 150 to 170 days. Since the townships are located 15 miles apart there also is little

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[3] Eugene Whiteside, Ivan Schneider and Ray Cook, Soils of Michigan, Special Bulletin 402, Michigan State University, East Lansing, Michigan, 1956, pp. 39-46.

[4] Statement by Eugene Whiteside, personal interview.

variation in the amount of rainfall per season and the date of freezing.[5]

Present Land Use

Lapeer county, in which both townships under study are located, is a major dairy and cash crop area. It is close enough to the large nearby markets to favor dairy production and general farming. Dairying is the most important enterprise for the area and on many farms it is the sole source of income. The number of dairy cows per farm is among the highest areas in the state. Dry field beans, wheat, and corn are the major cash crops. The ten year, 1942-1951, average crop yields for Lapeer and two surrounding counties were: corn 32 bushels, oats 38, wheat 24, barley 27, field beans 14 bushels, and hay 1.4 tons per acre. The average size of farms in 1950 in Lapeer county was 117 acres.[6]

Data Emmeration

The sample of farms for this study is composed of dairy farms from Almont experimental township paired with dairy farms from the matching Burnside control township.

The farms for the experimental township sample were selected after checking the county Agricultural Stabilization Committee records of

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[5] Elton Hill and Russell Mawby, Types of Farming in Michigan, Special Bulletin 206, Michigan State College, East Lansing, Michigan, 1954, p. 9.

[6] Ibid., p. 34.

the 181 farms in the experimental township with the township agent, project evaluator, and the board of directors of the Almont Township Extension Association.

A schedule (see Appendix A) was designed to furnish the total dollar value of output in 1953 including inventory changes, and the quantities of various resources employed during that year in producing that output. The 1953 data were enumerated in 1954 by a field survey team. The total interview for traditional farm account data, Cobb-Douglas data and a net worth statement took approximately two to three hours per farm. About one hour per farm was used to acquire the special data for Cobb-Douglas analysis. The special information collected for Cobb-Douglas analysis included the following items:

Forage investment (page 3, Appendix A)

a. Cost of perennial seeds and plants used in 1953.

b. Hay and pasture inventory on January 1, 1953. This included the kind, acres, age and condition of all hay and pasture fields and the month that any field was plowed down during the year.

c. The cost of machinery hired for normal land reclamation was also recorded for this category.

Livestock Investment (Pages 4-5, Appendix A)

Beginning inventory value of all breeding stock plus the number of cattle raised, or died, and the number, value, and month in which any breeding stock were purchased or sold during the year.

Machinery Investment (Pages 5-6, Appendix A).

The January 1, 1953 auction value of all machinery and equipment including the farm share of the auto. In addition the date and value of any machinery or equipment purchased or sold during the year were recorded.

Cash Expenses (Page 11, Appendix A)

Although all cash expenses were collected for traditional farm management analysis only a portion of some items were included and some entire items were deleted for Cobb-Douglas analysis.

Building Capacity (Page 8, Appendix A)

Data were collected on farm building capacity for all breeding livestock. The return to this category was not computed in this study.

Gross Income (Pages 4, 8-10, Appendix A)

In addition to the information on cash receipts and inventory changes in livestock, feed, and seeds, the value of family living furnished by the farm was collected for Cobb-Douglas analysis.

All information collected was treated as confidential; some farmers were reluctant to disclose financial information unless it would be used only for research at Michigan State University.

The farms for the control township were selected after checking the county Agricultural Stabilization Committee's statistics for the 251 farms in that township with the project evaluator, county agent, preceding county agent, and members of the survey team. On the basis of Tremblay's[7] pairing of farms in the Vermont Farm Planning Study, 38 farms in the control township were paired with the 38 farms in the experimental township. These farms were paired as closely as possible on the basis of the following factors: labor force available, age of the operator, total acres, tillable acres, number of cows, and the machinery investment. Two additional schedules were completed in the control township making a total of 40 schedules collected for the control township and 38 in the experimental township.

The following empirical techniques were used in this study in order to satisfy the condition that all farms are operating on the same production function as outlined by Teon and quoted in Chapter II of this study:

1. The sample was restricted to single enterprise dairy farms which derived the major portion of their gross farm income from the sale of dairy cattle and dairy products.
2. Data were secured for the year 1953.
3. All five input and investment categories were used on all farms in the samples.
4. Prices of feed, seed, livestock were held constant for the beginning and ending inventories. This allowed the marginal value productivity estimates to reflect the true earning

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[7] Raymond Tremblay, "Vermont Farm Planning Study," (Department of Agricultural Economics, University of Vermont, Burlington, Vermont, 1953), p. 1.

power of the input and investment categories rather than be biased by the effects of inflation or deflation of farm prices during the year of the study.

5. The two samples were restricted to soil associations having the same inherent productive capacity.

Purposive sampling was used to select a wide range of quantities and proportions of inputs used. This method allows a smaller number of farms that are not in competitive adjustment to be used in a sample than random sampling or farm record project samples permit. This procedure reduces the correlation between inputs which in turn reduces the standard errors of the regression coefficients. Purposive sampling also reduces the cost of collecting data as compared to random sampling because of the smaller number (30-40) of farms required for a sample.

On the basis of these conditions information collected on the 38 farms in the experimental and 40 in the control township included:

X_1 = Gross income measured in dollars

X_2 = Land, measured in total tillable acres

X_3 = Labor, measured in total months used on the farm

X_4 = Expenses, current operating, measured in dollars

X_5 = Livestock-forage investment, in dollars

X_6 = Machinery investment, in dollars

Gross income (X_1). This includes sales of all crops, livestock and livestock products; plus or minus changes in inventory of feed, seeds, crops, livestock or other farm-produced products; and the value of family living furnished by the farm. Government payments were excluded as they were not considered income from farm-produced products. Changes in inventory value of buildings and machinery due to depreciation were excluded from gross income. Therefore, gross income should be large enough in this study to cover the maintenance of the machinery and building investment. The value of farm buildings was not counted as an input in this study; so gross income does not include the rental value of the farm residence.

Land (X_2). This category includes the total number of acres of land owned, rented, or leased by the operator. It was measured in tillable acres. Both townships are highly developed, so practically all productive land is being utilized. In order to obtain an accurate estimate of the productivity of land, all land in woods, nontillable pasture, roads and building sites were excluded from this input category. The dollar value of land is difficult to estimate, therefore, land was measured in physical terms.

Labor (X_3). Labor was measured in total months of labor used on the farm during the year. This includes the operator's labor plus hired and family labor. If the operator worked off the farm part-time, the time he spent off the farm was deducted from the number of months (usually twelve months) he might have spent on the farm.

Current operating expenses (X_4). Included are all current operating expenses expected to yield dollar for dollar returns in a given year. It includes the following items: feed purchased, annual seeds and plants purchased, custom work or machinery hired, gas and oil for farm use, livestock expense, fertilizer and lime expense, farm share of electricity and telephone, farm share of the auto and truck gas and oil, feeders purchased, value of clover stands destroyed during the year, beginning inventory value of feeder livestock, and the value of perennials plowed down during the year.

The cost of lime was included in the expense category because the farms in both townships that did apply lime during 1953 all used the normal maintenance rate of application. The cost of fertilizer was also included in the expense category as no excessive rates of application during 1953 were encountered on the sample farms.

Beginning inventory value of feeder livestock plus the value of feeders purchased during the year were treated as an expense item, as feeders are expected to return a dollar for each dollar invested during the year.

Livestock and forage investment (X_5). This includes the dollar value of the investment in forage crops and breeding livestock for the 1953 year. Because of the high complementarity existing between forage and forage-consuming livestock, the two were combined into one category. The investment figures were computed separately for forage and livestock. Then the two were combined into this category. The total forage investment was computed by taking the beginning of the year inventory value of all hay and pasture stands, plus the cost of machinery hired for land reclamation and the cost of perennial seeds purchased during the year, minus a proportional credit for hay and pasture stands destroyed during the year. Beginning inventory value of hay and pasture stands included the cost of labor, seed and

fertilizer of establishing stands plus the subjective value of the stand in future years. Wagley and members of the Soil Science Department of Michigan State University computed the series of prices which were used for hay and pasture stands ranging from $28.22 per acre for first-year alfalfa-brome stand in excellent condition to $7.07 for third-year alfalfa-brome stand in poor condition to $5 per acre for permanent June grass and second-year clover stands.[8] The age, condition, name of each grass or legume, and the number of acres in each hay or pasture field was recorded on each surveyed farm schedule in order to determine the beginning of the year inventory values.

The livestock investment was computed by taking the beginning inventory of breeding stock plus proportional credit for breeding stock purchased during the year minus proportional credit for breeding stock sold during the year.

Machinery investment (X_6). Included in this category is the entire machinery investment for 1953. It is composed of the January 1, 1953, auction value of all machinery and equipment, plus a proportional credit for machinery purchased during the year, minus a proportional deduction for machinery sold during the year. The minimum return to the machinery investment must be high enough to cover maintenance, depreciation, interest, plus whatever subjective returns deemed necessary by the manager.

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[8]Based on unpublished data on estimated establishment costs for forage crops and small grains, compiled by Harry Wilt, Department of Agricultural Economics, Michigan State College.

The Sample Farms

The nature of the sample farms may be derived by showing the range in the data for the several categories of variables studied and the "usual"[9] farm organization.

The "usual" organization for the farms in the experimental township and control township is shown in Table 1.

TABLE 1

COMPARISON OF THE GEOMETRIC MEAN ORGANIZATION OF THE EXPERIMENTAL TOWNSHIP WITH THE CONTROL TOWNSHIP, 1953

Input Category	Experimental Township	Control Township
X_2 Land, acres tillable	142.1	153.3
X_3 Labor, months	18.4	17.2
X_4 Cash expenses	$3,271	$3,488
X_5 Livestock-forage investment	$7,227	$7,078
X_6 Machinery investment	$6,073	$6,148

A comparison of the "usual" organizations in the two townships points out the high degree of similarity in the quantity of inputs used. Little variation in cash expenses, or machinery investment was found in the two townships while a small difference in the amount of land, labor inputs and machinery investment existed. The "usual" organization of the control farms had eleven acres more land with one month less labor than the "usual" farm organization. The combination

[9]The usual organization is considered to be at the geometric means of the various input categories.

of resources in Burnside control farms yielded a gross income of $11,065 or $601 more than the Almont gross income of $10,464. The range in gross income, inputs, and investments in the two townships is shown in Table 2.

TABLE 2

COMPARISON OF THE RANGE IN INPUTS, INVESTMENTS, AND GROSS INCOME IN THE EXPERIMENTAL AND CONTROL TOWNSHIP, 1953

Category	Experimental Township	Control Township
Gross income	\$4,576-\$29,951	\$3,583-\$21,818
Land	33-361	75-328
Labor	8-42	6-38
Cash expenses	\$1,268-\$7,116	\$1,277-\$9,084
Livestock-forage	\$3,610-\$23,096	\$4,131-\$13,102
Machinery	\$2,565-\$15,006	\$2,101-\$13,393

The total of 78 schedules, (40 from the control township and 38 from the experimental township) were carefully analyzed. Since the Cobb-Douglas function provides reliable estimates for only single enterprise farms, it was necessary to select a homogeneous sample of dairy farms that derived their major portion of gross farm income from the sale of dairy products and dairy cattle. Thirteen schedules which failed to satisfy the homogeneous dairy type-of-farming classification or other accounting requirements were deleted from this study.

Five of the 38 experimental township farms were deleted for the following reasons: two were fruit farms, two farms operated only nine months during 1953, and one was a cash crop farm. This left 33 usable schedules for the experimental township function.

Eight schedules of the original 40 were deleted from the control township sample for the following reasons: three were beef cattle farms, two had incomplete schedules, one was a poultry farm, one farmer was a cattle dealer, and one farm had only one cow. This left 32 usable schedules for the control township function.

Fitting the Function

A total of 65 schedules, 33 for the experimental township and 32 for the control township were used to fit the first Cobb-Douglas function. The totals of each input and investment category and gross income on the 65 schedules were converted into logarithms.

The Doolittle[10] method of multiple correlation analysis was used to fit two least squares regression equations to the logarithms of the data; one for the thirty-three farms in experimental township and one for the thirty-two farms in control township.

The Experimental Township Results

The regression coefficients and associated standard errors that were obtained by fitting the function to the 33 experimental township farms were:

Land	$b_2 = .289740 \pm .126122$
Labor	$b_3 = .160090 \pm .118746$
Expenses	$b_4 = .284260 \pm .122984$
Livestock-forage	$b_5 = .322018 \pm .128456$
Machinery	$b_6 = .139422 \pm .141520$

[10] Ezekiel, op. cit., Appendix I.

The constant (log a) was computed and found to be .424494. In natural numbers the fitted regression equation was:

$$X_1 = .424494 \cdot X_2^{.289740} X_3^{.160090} X_4^{.284260} X_5^{.322018} X_6^{.139422}$$

The geometric mean combination of inputs for the experimental township yielded a gross income of $10,464.

Least squares regression analysis provides three types of information about regression coefficients--the amount of change, the proportionate importance, and the accuracy of the estimate.[11] The amount of change is indicated by the value derived for the regression coefficient, the proportionate importance by the correlation, and the accuracy of the estimate by the standard error. These three factors were used to appraise the regression coefficients for the experimental and control townships.

The amount of change as reflected by the regression coefficients was believed to be accurate for all inputs and investments in the experimental township. The amount of change occurring in gross income with a one percent increase in the amount of land to the production process is equivalent to .289740 which is the regression coefficient for the land. Since all regression coefficients are less than one decreasing returns to scale are being experienced for all inputs and investments.

The usefulness of regression coefficients depends upon their accuracy. The standard error of a regression coefficient determines

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[11] Trant, op. cit., p. 37.

the degree of accuracy and is dependent upon three main factors: size of the sample, range in the observation of the independent variable, and the intercorrelations between the independent variables for which the regression coefficients are estimated. The influence of each of these factors upon the standard error was discussed in Chapter II on page 45.

The multiple correlation coefficient or (R) was .91. Under conditions of random sampling, with five independent variables and one dependent variable, a multiple correlation coefficient this high would be expected in one sample out of 20 if the true multiple correlation coefficient were .80. Consequently, the degree of correlation is significant.

The coefficient of determination (R^2) of .84 indicated that 84 percent of the variance in gross income (X_1) is associated with variations in the input and investment categories. The remaining 16 percent of the variation in X_1 may be due to nonstudied variables.

The standard error of estimate ($\overline{S}$) of the dependent variable (gross income) was computed to be .087934. The logarithm of gross income at the geometric mean was 4.019703, the antilog of which is $10,464. Under conditions of random sampling, given the weather and price conditions for 1953, 67 percent of the time the logarithms of actual gross income would be expected to fall within the range of 4.019703 $\pm$ .087934 or, in natural numbers, between $8,546 and $12,813. According to these results, on the average, one farm out of three of the usual organization would be expected to have a gross income greater than \$12,813 or less than \$8,546.

Estimated marginal value products. The marginal value product estimates are shown in Table 3:

TABLE 3

USUAL ORGANIZATION AND ESTIMATED MARGINAL AND GROSS VALUE PRODUCTS, THIRTY-THREE EXPERIMENTAL TOWNSHIP FARMS, 1953

Input Category	Quantity of Inputs	Log X_1	bi's	(Log X_1·bi)	MVP
Land	142.1	2.152576	.289740	.623687	\$21.33
Labor	18.4	1.263664	.160090	.202278	\$91.24
Expenses	\$3,271	3.514656	.284260	.999076	.91
Livestock-forage	\$7,227	3.858956	.322018	1.242653	.47
Machinery	\$6,073	3.783426	.139422	.527515	.24
Log constant (a) -	...	...		.424494	
Log X_1 (Gross Income) = Log a + (bi.X_1) =				4.019703	

The marginal value products represent the net return to the last unit of each input or investment category. For example the last acre of land was earning \$21.33, the last month of labor was earning \$91.24, the last dollar of cash expenses was returning 91 cents while the livestock-forage investment was earning a 47 percent return and the machinery investment a 24 percent return.

The accuracy of the regression coefficients and hence the marginal value products depends on their standard errors. As discussed previously the intercorrelation between independent variables is an important factor in determining the size of the standard errors. The simple correlations that existed between independent variables were as follows:

r23	.61	r24	.57	r25	.62	r26	.60
r34	.29	r35	.45	r36	.32		
r45	.61	r46	.70				
r56	.72						

Two high correlations were observed between cash expenses and machinery investment of .70 (r46) and between livestock-forage investment and machinery investment of .72 (r56). These correlations must be taken into consideration when the marginal product estimates for expenses, machinery and livestock-forage are interpreted.

The significance of the marginal value product estimates is closely related to the significance of the regression coefficient estimates. One method of determining the significance of the regression coefficients is to test them against zero as a null hypothesis.[12] This is the simple student's t test that is computed by dividing a regression coefficient by its standard error. The coefficients b_2 (land), b_4 (cash expenses) and b_5 (livestock-forage investment) were significantly different from zero at the five percent level, while b_3 (labor) was not significantly different from zero at the five percent level, and the standard error of b_6 (machinery investment) was larger than the regression coefficient of machinery. The t values for land, expenses, and livestock-forage investment were larger than 1.96 and less than 2.56 which means that in 95 out of 100 cases if functions were fitted to different samples

12 Assumes that the difference between the estimated coefficient and the actual coefficient is null or zero.

from the same population the regression coefficients would be as large or larger than the estimated coefficients for this function.

A set of minimum expected returns for the input and investment categories were used to test the actual regression coefficients of the sample against the minimum regression coefficients necessary to give marginal productivities equal to the market price or marginal factor cost of the resources. In other words, does the marginal return of $91.24 per month of labor differ significantly from $150, the market wage rate[13] (plus room and board) for labor in the dairy farming section of eastern Michigan or do the $.91 returns differ significantly from the $1.00 cost of cash expenses? As a test of these possibilities, the regression coefficients of production necessary to give marginal products equal to the market cost of the resources were computed.

The following set of minimum expected returns were considered to be reasonable minima to expect:

Labor	$150.00 per month[14]
Land	$10.00 per acre[15]
Cash expenses	$1.00 per dollar expended
Livestock-forage investment	40% of investment
Machinery investment	20% of investment

The regression coefficients or bi's of each input or investment are compared with a "standard" bi capable of yielding a marginal value product equal to the marginal factor cost for each input or

[13] Karl Vary, "Wage Rates Reported by Farmers," Michigan Farm Economics, Cooperative Extension Service, Michigan State College, August, 1953.

[14] Ibid.

[15] Based on 5% interest rate with land valued at $200 per acre.

investment. The "standard" bi is determined after solving the equation $MVP = \frac{bi\ E(Y)}{X_i}$ for the bi after the minimum marginal value product has been determined and substituted in the equation. The estimated b_i is subtracted from the standard b_i and the difference is divided by the standard error of the b_i. The results of the test are shown in Table 4.

TABLE 4

COMPARISON BETWEEN THE ESTIMATED REGRESSION COEFFICIENTS AND THE REGRESSION COEFFICIENT REQUIRED TO YIELD THE MARKET PRICE OF RESOURCES FOR THIRTY-THREE EXPERIMENTAL TOWNSHIP FARMS, 1953

Input	Estimated bi's	bi to yield Minimum Return	bi-bi*	σbi	$\frac{bi-bi}{\sigma bi}$
Land	.289740	.135798	.153942	.126123	1.220570
Labor	.160090	.263761	.103671	.118746	.873048
Expenses	.284260	.312882	.028622	.122984	.232729
Livestock-forage	.322018	.278172	.043846	.128456	.341330
Machinery	.139422	.116081	.023341	.141520	.164930

*Absolute value.

Only the land regression coefficient is significantly different from the "standard" bi required to equate marginal factor cost and marginal value product of land. Thus it appears that the farms are well adjusted when analyzed at their geometric means.

Comparison of Experimental Township Estimates with Wagley's Estimates. The most recent Cobb-Douglas study of dairy farms in

Michigan was conducted by Wagley in 1952. He selected 33 dairy farms in Ingham County (central Michigan, about 90 miles from the experimental township) and derived the following marginal value products: land, $16; labor, $30; expenses, 76 percent; livestock-forage, 64 percent; and machinery, 19 percent. By comparing the experimental township returns with Wagley's estimates it is seen that the returns are within a close range of each other.

Acceptance of the Function for the Experimental Township. The first function for the experimental township was accepted as being an accurate measure of the earning power of the inputs and investments used on dairy farms in the experimental township. The estimated returns to the input categories have low standard errors and are within a narrow range of the minimum expected returns that are considered necessary for the dairy area in which the experimental township is located.

Appraisal of the First Function for the Control Township

A total of 32 farms were used to fit the first function for the control township. The regression coefficients and associated standard errors for the control township were:

Land	$b_2 = -.089608 \pm .151361$
Labor	$b_3 = .236034 \pm .135821$
Expenses	$b_4 = .331256 \pm .134847$
Livestock-forage	$b_5 = .439135 \pm .124759$
Machinery	$b_6 = .259361 \pm .116840$

The amount of change for the input and investment categories that was reflected in the control township's regression coefficients was believed to be accurate for all inputs except land and labor. A negative elasticity of -.089608 was obtained for land. This means that increased quantities of land might possibly decrease gross income but it was not believed probable that it would do so. Tintner and Brownlee pointed out that: "negative elasticities, within the range of inputs on most farms are meaningless."[16]

The simple correlations between the independent variables were found to be:

r23 - .74	r24 - .32	r25 - .52	r26 - .62
r34 - .29	r35 - .44	r36 - .49	
r45 - .50	r46 - .61		
r56 - .51			

Relatively high correlations between land and labor of .74 (r23), land and machinery of .62 (r26), and expenses and machinery of .61 (r46), were partly responsible for the high standard error and reduced reliability of the regression coefficient for land. Thus, with a given amount of variance in the dependent variable that can be explained in the "best least squares fit" by the independent variables, overestimation of one regression coefficient tends to necessitate some underestimation of one or more of the other regression coefficients.[17] This could be interpreted to mean that some of the underestimation in land coefficient might be due to an overestimation of either the labor, or machinery coefficients since both of these had high intercorrelations with the land input.

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[16] Tintner and Brownlee, op. cit., p. 37.

[17] Toon, op. cit., pp. 42-43.

Another factor responsible for the large standard error of land can be traced to the failure in the sampling procedure to select a wide range of data from imperfectly adjusted farms. It was found that a large percentage of the farms in the sample were well adjusted competitive firms. For instance, a cluster of farms with 12 to 14 months of labor and 130 to 150 tillable acres of land were discovered when data for the 32 farms in the sample were plotted on a simple graph. Therefore, the lack of range in the control data reduced the reliability of the regression coefficients by causing high standard errors for the coefficients.

Estimated Marginal Value Products. The marginal value products computed for the first control township function are shown in Table 5.

TABLE 5

USUAL ORGANIZATION AND ESTIMATED MARGINAL AND GROSS VALUE PRODUCTS THIRTY-TWO CONTROL TOWNSHIP FARMS, 1953, FIRST FUNCTION

Input Category	Quantity of Inputs	Log X_i	bi's	(Log X_i.bi)	MVP
Land	153.3	2.185565	-.089608	-.195844	$ -6.46
Labor	17.2	1.234260	.236034	.291327	$152.26
Expenses	$3,488	3.542559	.331296	1.173635	1.05
Livestock-forage	$7,078	3.849925	.439135	1.690636	.68
Machinery	$6,148	3.788704	.259361	.982642	.46
Log constant (a) =		...	...	.101568	
Log X_1 (Gross Income) = Log a + (bi.X_i) =				4.043964	

It is seen that the negative regression coefficient for land creates a negative marginal value product for land. It is believed that the returns to labor are partly reflecting the returns to land and hence in reality the actual marginal value product of land is positive while the return to labor is smaller than the estimated $152.26.

The unexplained residuals in gross income for each farm were computed in order to locate unusual discrepancies in data from sample farms or unusual circumstances in the method of grouping the input categories and handling the data. 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 actual gross income to determine the residual. Sizeable residual gross incomes of $3,698 and $6,517 were found on two farms while smaller residuals of $1,000 to $1,500 were discovered on several other farms. The two farms with actual gross incomes of $3,698 and $6,517 less than their expected gross incomes were re-interviewed during the fall of 1955. A gravel bed cutting across these two farms was found to be the major factor responsible for their actual incomes to be considerably lower than their expected gross incomes. Hence, these two farms were on a different production function than the other 30 farms in the sample and should be deleted for more accurate results.

The coefficient of determination for the control sample was computed to be .82 which may be interpreted as meaning that 82 percent of the variation in gross income (X_1) was associated with variations in the input and investment categories. The remaining 18 percent of the variation in X_1 may be due to non-studied variables that were assumed to be randomly and normally distributed. After comparing the residual gross incomes on each farm with the data on the survey schedule it was hypothesized that the wide variation in soil types on two farms was mainly responsible for the unexplained variance of 18 percent.

Rejection of the First Function for the Control Township. Since the negative coefficient for land was thought to be biased downward and the coefficient for labor was biased upward, due to a high intercorrelation between land and labor, the regression coefficients for the first control function were considered unreliable. The first function for the control township was rejected for the following reasons: 1) negative marginal value product estimate for land, 2) high MVP for labor, 3) large residuals of $3,698 and $6,517 on two farms, and 4) high degree of intercorrelation between several input categories.

Appraisal of the Second Function for the Control Township

A new function was fitted for the control township after deleting two farms that were located on a different soil type than the remaining sample farms. The "usual" organization of the thirty farms used to fit the second control township function as compared to the organization in the experimental township and to the organization of the farms used to fit the first control township function is shown in Table 6.

TABLE 6

COMPARISON OF THE GEOMETRIC MEAN AVERAGES OF INPUT CATEGORIES FOR THE FIRST AND SECOND CONTROL TOWNSHIP FUNCTIONS WITH THE EXPERIMENTAL TOWNSHIP FUNCTION, 1953

Input Categories	Control Township First Function 32 Farms	Control Township Second Function 30 Farms	Experimental Township 33 Farms
Land	153.3	149.8	142.1
Labor	17.2	16.8	18.4
Cash expenses	$3,488	$3,425	$3,271
Livestock-forage	$7,078	$6,913	$7,227
Machinery	$6,148	$6,049	$6,073

By examining Table 6 it is seen that the "usual" organization of all input and investment categories for the second control function is smaller than the "usual" organization of the first control function sample. This occurred because the two farms that were deleted for the second function had a larger amount of inputs and investments than the "usual" organization for the sample farms in the first function.

The combination of resources in the control township for the second function yielded a gross income of $11,148 which was $83 higher than that of $11,065 for the first function. Gross income ranged from a high of $21,818 to a low of $3,583.

The coefficients and associated standard errors that were obtained by fitting a Cobb-Douglas function to thirty farms were found to be:

Land	$b_2 = -.045852 \pm .110472$
Labor	$b_3 = .255119 \pm .098623$
Expenses	$b_4 = .356342 \pm .075420$
Livestock-forage	$b_5 = .507209 \pm .091942$
Machinery	$b_6 = .226173 \pm .084955$

The constant (log a) was computed and found to be -.228078. In natural numbers the fitted regression equation was:

$$X_1 = {}^{-.228078} \cdot X_2^{-.045852} \cdot X_3^{.255119} \cdot X_4^{.356342} \cdot X_5^{.507209} \cdot X_6^{.226173}$$

The multiple correlation coefficient (R) was .96. Under conditions of random sampling, with five independent variables and one dependent variable, a multiple correlation coefficient this high would be expected in one sample out of 20 on the average if the true multiple correlation coefficient were .89. Consequently, the degree of correlation is significant. Since extreme values were included in the sample, the value of the multiple correlation coefficient should be expected to be higher than that existing in the universe, though not higher than for a similarly drawn sample for the same universe.[18]

The coefficient of determination (R^2) of .91 indicates that 91 percent of the variance in gross income (X_1) is associated with variations in the input and investment categories. The remaining nine percent of the variation in X_1 may be due to nonstudied variables. The unexplained variance of 18 percent in the first control function

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[18] Ezekiel, op. cit., p. 320.

was reduced to nine percent in the second function after deleting two farms that were on different soil types.

The standard error of estimate ($\overline{S}$) of the dependent variable (gross income) was computed to be .059706. The logarithm of gross income at the geometric mean was 4.047192, the antilog of which is $11,148. Under conditions of random sampling, given the weather and price conditions for the year in which the sample was taken, 67 percent of the time, the logarithms of actual gross income would be expected to fall within the range of 4.047192 ± .059706 or, in natural numbers between $9,716 and $12,790. According to these results, on the average, one farm out of three of the usual organization would be expected to have a gross income greater than $12,790 or less than $9,716.

Estimated Marginal Value Products. The marginal value products were computed for the "usual" organization of the 30 farms in the second control function. The marginal value estimates are shown in Table 7.

By examining the MVP's it is seen that land still has a negative marginal value product while the marginal value products for labor, expenses and livestock-forage investment increased, and the marginal value product for machinery decreased.

The simple correlations that existed between independent variables were:

r_{23} .72	r_{24} .30	r_{25} .50	r_{26} .61
r_{34} .27	r_{35} .42	r_{36} .48	
r_{45} .47	r_{46} .60		
r_{56} .49			

TABLE 7

USUAL ORGANIZATION AND ESTIMATED MARGINAL AND GROSS VALUE PRODUCTS THIRTY CONTROL TOWNSHIP FARMS, 1953, SECOND FUNCTION

Input Category	Quantity of Inputs	Log X_i	bi's	(Log X_i.bi)	MVP
Land	149.8	2.175579	-.045852	-.099755	$ -3.41
Labor	16.8	1.225464	.255119	.312633	$169.11
Expense	$3,425	3.534666	.356342	1.259550	1.16
Livestock-forage	$6,913	3.839674	.507209	1.947529	.82
Machinery	$6,049	3.781674	.226173	.855313	.42
Log constant (a) =		...	...	-.228078	

Log X_1 (Gross Income) = Log a + (bi.X_i) = 4.047192

A small reduction in the correlations for each input category was noted for the second control township function as compared to the first control township function. Three of the ten correlations listed above dropped .03, while six dropped .02 and one dropped .01 after fitting the second function. Since the size of the sample for the second function was 30 as compared to 32 for the first function, it is seen that only a small reduction in each of the simple correlations occurred after fitting the second function. Three high correlations still exist after fitting the second function. These are: land and labor, r23 of .72 as compared to .74 in the first function; land and machinery, r26 of .61 as compared to .62 in the first function and expenses and machinery r46 of .60 as compared to .61 in the first function.

Comparison of the Two Functions for the Control Township. The purposes of fitting the second function to the control township were to attempt to: reduce the intercorrelation between independent inputs, secure a more accurate estimate for the land input, reduce the standard error of the bi's, and obtain more accurate marginal value product estimates for all input and investment categories. The effect of fitting the second function to the control township is shown in Table 8.

By examining Table 8 it is seen that all standard errors of the regression coefficients were reduced after fitting the second function; the marginal value product estimates were increased for all inputs except machinery; and the regression coefficients were increased for all inputs except machinery.

Rejection of the Second Function for the Control Township. After examining the results of the second function, the livestock-forage investment was questioned as it yielded an 82 percent return compared to a 68 percent return in the first control township function and a 47 percent return in the experimental township. Since the level of milk production in the control and experimental townships and the value of dairy cows in the two areas was assumed to be about the same, the cow values for each farm in the control township were plotted against the pounds of milk produced per cow on these farms. The same procedure was followed in the experimental township, and it was discovered that the dairy herds in the control township were undervalued compared to the herds in the experimental township. The average pounds of milk

TABLE 8

COMPARISON OF GEOMETRIC MEANS, REGRESSION COEFFICIENTS, STANDARD ERRORS AND MARGINAL VALUE PRODUCTS FOR TWO FUNCTIONS FITTED TO THIRTY-TWO AND THIRTY CONTROL TOWNSHIP FARMS, 1953

Category	Geometric Mean		Regression Coefficient bi's		Standard Error of bi's		Marginal Value Product MVP	
	I*	II**	I*	II**	I*	II**	I*	II**
Land	153.3	149.8	-.089608	-.045852	±.151361	.110472	$-6.46	$-3.46
Labor	17.2	16.8	.236034	.255119	±.135821	.098623	$152.26	$169.17
Expenses	$3,488	$3,425	.331296	.356342	±.134847	.075420	$1.05	$1.16
Livestock-forage	$7,078	$6,913	.439135	.507209	±.124759	.091942	.68	.82
Machinery	$6,148	$6,049	.259361	.226173	±.116840	.084955	.46	.42

*Function I fitted to 32 farms.
**Function II fitted to 30 farms.

produced per cow on the 30 control township farms was approximately 9,000 pounds compared to 8,300 pounds on the experimental township farms. The average livestock investment was $5,822 for 20 cows and other breeding livestock in the control township compared to an average livestock investment of $7,067 for 21 cows and other breeding livestock in the experimental township. After analyzing the livestock investments in the two townships it was discovered that the experimental township survey team of three interviewers valued cows about $50 higher for all production levels than the other survey team of three interviewers did in the control township. Hence, the livestock investment of $5,822 in the control township compared to a $7,067 investment in the experimental township was due to undervaluing the control township herds.

On the basis of the undervalued livestock-forage investment in the control township the second function for the control township was rejected.

Fitting the Third Function to the Control Township

The livestock investment on 26 farms in the control township was adjusted upwards by checking each schedule and placing a value on the dairy herd corresponding to the value of the cows with the same milk production in the experimental township. The geometric mean value of the livestock-forage investment increased from $6,913 to $7,644 or $731 after revaluing the herds on 26 farms in the control township. One other minor discrepancy in the forage investment was noted in the control township. It was discovered that on eight control township farms alfalfa-brome fields plowed down in June were counted as part of the forage investment rather than as a cash expense. The forage investment on these farms was adjusted for this factor and hence the forage investment for the third function decreased while cash expenses increased. The cash expense category increased from \$3,425 to \$3,538 or \$113 after the changes were made in the forage and cash expenses for the eight farms in the control township.

The third function was fitted to the same 30 farms as the second function. Changes in the livestock-forage investment and cash expense were made so that the geometric mean average of the livestock-forage investment increased from \$6,913 in the second function to \$7,644 in the third function and cash expenses increased from \$3,425 to \$3,538.

Appraisal and Acceptance of the Third Function for the Control Township. The results of fitting the third function to the control township data are presented in Table 9.

The constant (log a) was -.151903. In natural numbers the fitted regression equation was:

$$X_1 = -.151903 \cdot X_2^{-.025360} \cdot X_3^{.186111} \cdot X_4^{.348558} \cdot X_5^{.556546} \cdot X_6^{.166067}$$

This combination of inputs and investments was expected to produce a gross income of \$11,148.

The null hypothesis was used to test the probability that the regression coefficients obtained from a different sample of the same population would be as large or larger than the estimated regression coefficients. The regression coefficients, b_4 (for expenses) and b_5

TABLE 9

THE GEOMETRIC MEAN ORGANIZATION, REGRESSION COEFFICIENTS, STANDARD ERRORS AND MARGINAL VALUE PRODUCTS FOR THIRTY CONTROL TOWNSHIP FARMS, 1953, THIRD FUNCTION

Input Category	Mean	Regression Coefficients	Standard Errors of Regression Coefficients	MVP
Land	149.8	-.025360	.106929	$ -1.89
Labor	16.8	.186111	.096064	$123.42
Expenses	$3,538	.348558	.072420	1.10
Livestock-forage	$7,644	.556546	.094148	.81
Machinery	$6,049	.166067	.082293	.31

(for livestock-forage investment), were significantly different from zero at the one percent level of significance; b_3 (for labor) and b_6 (for machinery investment) were significantly different at the five percent level and the standard error of b_2 (for land) was larger than b_2.

The estimated bi's are compared with the bi's capable of yielding a marginal value product equal to the marginal factor cost in Table 10.

It appears from this test that when the regression coefficients are compared at their geometric means only the land and livestock-forage are significantly different from the "standard" bi required to equal marginal factor cost and marginal value product.

The multiple correlation coefficient or (R) was .96. The coefficient of determination or (R^2) was .92 compared to .91 in the second function. This means that 92 percent of the gross income can

TABLE 10

COMPARISON BETWEEN THE ESTIMATED REGRESSION COEFFICIENTS AND THE REGRESSION COEFFICIENTS REQUIRED TO YIELD THE MARKET PRICE OF RESOURCES FOR THIRTY CONTROL TOWNSHIP FARMS, 1953, THIRD FUNCTION

Input	Estimated bi's	bi to Yield Minimum Return	bi-bi*	σbi	$\frac{bi-bi}{\sigma bi}$
Land	-.025360	.134373	.159733	.106929	1.493823
Labor	.186111	.226049	.039938	.096064	.324700
Expenses	.348558	.317366	.031192	.072420	.430709
Livestock-forage	.556546	.274219	.282327	.094148	2.998757
Machinery	.166067	.109139	.056928	.082293	.691772

* absolute value

be explained by the five inputs and investments (X_2--X_6). The standard error of estimate ($\bar{S}$) was .031912. This means that 67 percent of the time the actual gross income for the farms under study would fall within the range of 4.047192 $\pm$ .031912 or, in natural numbers, between $10,359 and $11,997.

The comparison of the statistical tests for the three functions fitted to the control township are shown in Table 11.

By examining Table 11 it is observed that the following changes were recorded after fitting the third function to the control township: the multiple correlation coefficient increased from .91 to .96; the coefficient of determination increased from .82 to .92 which means that 92 percent of the variation in gross income is explained by the

TABLE 11

COMPARISON OF NUMBER OF FARMS, GROSS INCOME, MULTIPLE CORRELATION COEFFICIENT (R), COEFFICIENT OF DETERMINATION (R^2), STANDARD ERROR OF ESTIMATE ($\overline{S}$) AND THE SUM OF REGRESSION COEFFICIENTS FOR THREE FUNCTIONS FOR 32 AND 30 FARMS IN THE CONTROL TOWNSHIP, 1953

Item	Control Township		
	Function I 32 Farms	Function II 30 Farms	Function III 30 Farms
Number of farms	32	30	30
Gross income (X_1)	$11,065	$11,148	$11,148
(R)	.91	.96	.96
R^2	.82	.91	.92
$\overline{S}$	.08	.06	.03
Sum of regression coefficients	1.28	1.30	1.23

input categories, as compared to 82 percent in the first function and the standard error of estimate of gross income was reduced.

The intercorrelations between input categories were as follows:

r23 - .72	r24 - .24	r25 - .61	r26 - .61
	r34 - .23	r35 - .55	r36 - .48
		r45 - .50	r46 - .56
			r56 - .62

The only sizeable change in the intercorrelations after fitting the third function was between livestock-forage investment and machinery, r56 of .62 compared to .49 in the second function. After plotting the livestock investment on each of the 30 farms against the machinery investment and likewise the forage investment against the machinery investment it was discovered that forage investment was highly correlated with the machinery investment. The same machinery investment had a marginal value product of .42 in the second function compared to .31 in the third function. It appears that the return for livestock-forage investment was overestimated while the machinery investment was underestimated. After the livestock-forage investment was increased $731 in the third function, the marginal value product dropped only one percent or from .82 to .81. In view of this small reduction of one percent it is believed that the higher correlation of .62 for livestock-forage investment with the machinery investment is responsible for the sharp reduction in the marginal value product of machinery while only a slight decline occurred in the livestock-forage investment.

In spite of several limitations caused by high intercorrelation between land and labor and livestock-forage investment and machinery investment the third function was accepted as a good measurement of economic efficiency in the control township for the benchmark year of 1953 for the following reasons: 1) a further reduction in the size of the sample for fitting another function would only tend to increase the standard errors of the bi's as the smaller the sample size, the larger the standard errors; 2) no accurate schedules were available for substitution or for increasing the size of the sample for another fit; 3) five farm account records for the control township for 1953 were analyzed and found unusuable because of accounting difficulties and lack of sufficient data for all input categories, and 4) no sizable reduction in any of the simple intercorrelations was experienced after

fitting the third function and further "fits" were not believed to cause any great reduction.

Reorganization of the Experimental and Control Township Farms

The purpose of this section is to suggest reorganization patterns for the two townships on the basis of their estimated regression coefficients, statistical tests, and judgment. The purpose of reorganizing farms is to achieve a more efficient production pattern for profit maximization or nonmonetary reasons such as insurance, and flexibility that may enter the decision making process. For this section the profit maximizing goal of farm families is taken to be of primary importance. Expanding the use of assets until a more efficient level of operation is reached offers an avenue of profit maximization. There are many limiting obstacles that slow down or prevent farm firms from making reorganization plans for achieving greater efficiency. Some of these are institutional factors such as capital rationing, acreage controls, lack of available inputs (such as no land for sale within ten or fifteen miles from the farm site), and personal factors (such as old age and religious beliefs). These factors will not be considered in this section. The recommendations for the experimental and control township will be brief and based only on the general approaches that may apply to the mean average of the farms but not specifically to any one farm in the sample.

Experimental Township

The 32 farms provided the following marginal value estimates: land, $21 per acre; labor, $91 per month; expenses, 91 cents; livstock-forage, 47 percent; and machinery, 24 percent. On the basis of these estimates the following adjustments should be made: expand land and livestock-forage production for their return exceeds their marginal factor costs; reduce labor and cash expenses for their return is less than their marginal factor cost; and use the present amount of machinery. On the basis of the statistical tests and judgment these recommendations seem to be in line. The proposed expansion of land in this experimental township has been verified by a recent survey in early 1956. In this survey 28 experimental township farmers increased their tillable acres of land to 177 as compared with 151 in the benchmark study. This indicates a 15 percent expansion in tillable acres of land in two years.

On the basis of the marginal value product estimates the expected gross income for each farm in the sample can be computed. This involves taking the actual quantities of inputs and investments used and the regression coefficients in order to derive the estimated gross income. For example, the first farm surveyed in the experimental township had an actual gross income of $6,820 compared to an estimated gross income of $7,082. Hence the estimated regression coefficients for this study could be used to estimate the gross income for each farm and the individual farm operator could compare his actual gross income with his expected gross income. One of the limitations of this type of analysis from the standpoint of the individual farmer is that he can use the data only insofar as he approximates the average farmer. The marginal value products are calculated at the geometric mean therefore the individual farmer cannot rely on his production function being exactly the same as the average of the farms surveyed. In addition Cobb-Douglas results do not provide farmers with information as to the item of machinery or the age of breeding livestock to purchase, or what expense items to change if these categories should be contracted or expanded. It also does not indicate whether the forage investment should be expanded to include more alfalfa-brome or clover hay. This forces the extension agent or researcher using the results of these studies to bring other types of analysis such as budgeting or linear programming into play so that the alternative costs and returns from expanding individual items can be computed before successful reorganization plans can be adopted.

Control Township

The 30 farms in the control township sample provided the following marginal value product estimates: land, $1.89 per acre; labor, $123 per month; expenses, $1.10 return on the dollar; livestock-forage, 81 percent; and machinery, 31 percent return for 1953. On the basis of these estimates the following adjustments will lead to more efficient production: expand expenses, livestock-forage, and machinery, for their return exceeds the marginal factor cost;

reduce land and labor, for their return is less than the marginal factor costs of using these items. On the basis of the returns, statistical tests, and judgment, it appears that the recommendations should be altered so that land is expanded rather than contracted. This recommendation is based on the high correlation between land and labor and the sum of the regression coefficients being greater than but not significantly greater than one. This indicates that the returns to land are undervalued while labor is overvalued. In reality it appears that land and labor should be appraised together, as their high correlation has considerable influence on the estimated negative returns to land. The recommendation for expanding livestock-forage investment will perhaps require additional land to increase the forage investment. It is possible that the quality of the present forage stands could be increased without purchasing any more land, but a sizeable forage expansion would require additional land to be purchased.

CHAPTER IV

STATISTICAL RESULTS AND SUGGESTED STATISTICAL TESTS TO USE IN EVALUATING THE CHANGES IN ECONOMIC EFFICIENCY AT THE COMPLETION OF THE EXPERIMENT

In order to determine what changes take place during an experiment, it is necessary to establish a benchmark or starting point. The purpose of the first part of this chapter is to establish a benchmark level of efficiency for the experimental and control township for 1953 on the basis of the Cobb-Douglas results. If the townships were closely matched there should be little difference in the earning power of the inputs and investment for the benchmark year of 1953. Thus the 1958 estimates in the experimental and control townships can be compared to the 1958 common benchmark level of efficiency. If the Cobb-Douglas functions indicate that different benchmark levels of efficiency existed in the two townships then the terminal estimates for each township are compared to their benchmark levels. Therefore, if one experimental and its matching control township have the same or different level of benchmark efficiency, it is possible to compute the change in efficiency resulting from the five year experiment.

Interpretation of Cobb-Douglas Results in the Two Townships

The geometric mean organization and marginal value products of the accepted experimental and control township functions are compared in Table 12.

TABLE 12

COMPARISON OF QUANTITY OF INPUTS AND MARGINAL VALUE PRODUCTS IN THE EXPERIMENTAL AND CONTROL TOWNSHIPS, 1953

Input Category	Quantity of Inputs		Marginal Value Products	
	Experimental	Control	Experimental	Control
X_2 Land	142.1	149.8	$21.33	$-1.89
X_3 Labor	18.4	16.8	$91.24	$123.42
X_4 Cash expenses	$3,271.	$3,538.	.91	1.10
X_5 Livestock-forage	$7,227.	$7,644.	.47	.81
X_6 Machinery	$6,073	$6,049.	.24	.31

Comparison of Marginal Value Products

Land. The marginal value product of $21 for land in the experimental township appears to be in line with the expectations for the area. With land valued at $200 per acre in the area it should return at least $10 per acre if a five percent capitalization value is used as recommended by farm management extension specialists. Since land has a high intercorrelation (.61) with the labor input, it is possible that the actual return for the last acre of land is slightly less than the $21 per acre while the labor MVP is slightly higher than the estimated $91.

The MVP for land in the control township function was a negative $1.89 per acre. A somewhat low or negative return to the last acre of land might be expected if the land were in a raw and unproductive state, and further, if only a small amount of resources (livestock-forage) were combined with land. However, since a $7,644 livestock-forage investment was combined with the land input, it was concluded that land should earn from $5 to $10 per acre if the five percent capitalization rate is used on the $200 per acre market value of land. It was hypothesized that in reality, land was earning more at the margin than the reported negative $1.89 per acre.

It appears that the experimental township is making more efficient use of the land than the control township. However, due to high correlations with land and labor in the control township it appears that land is underestimated and that actually there is little difference in the level of land efficiency in the two townships.

Labor. The MVP of labor for the experimental township was $91. The high intercorrelation between land and labor may be partly responsible for a lower MVP for labor. On some farms it is believed that the months of labor used per farm during the year were over-estimated thus causing the MVP to be slightly lower than it is in reality. On many farms an accurate record of the family labor was not kept and in some cases 12 months of labor were reported by the operators even though they were not fully productive during the winter months.

The MVP of labor of $123 for the control township is believed to be slightly overestimated since the high intercorrelation between land and labor causes the labor input to partly account for some of the returns for land.

The MVP results indicate that the control township has slightly greater labor efficiency than the experimental township. However, due to high correlations between land and labor in the control township, it appears that there is little difference in the level of labor efficiency in the two townships.

Cash expenses. The MVP of cash expenses for the experimental township was 91 cents on the dollar or slightly below the minimum expected dollar for dollar return. Since cash expenses such as fertilizer, gas and oil, and feed, are expected to return at least one dollar for every dollar expended during the year it is believed that cash expenses were being quite efficiently utilized on the experimental township farms.

The MVP of cash expenses for the control township of $1.10 for each dollar expended during the year reveals a high rate of return on this input.

The returns indicate that there is little difference in the level of efficiency for cash expenses in the two townships.

Livestock-forage investment. The MVP for livestock-forage investment of 47 percent for the experimental township farms reveals that this category is being used efficiently, as it approaches the marginal factor cost of 40 percent. The returns for the experimental township appear to be high on the surface to many extension agents and farmers, but after careful examination of the forage and livestock investments it is seen that a 40 percent return is necessary to cover depreciation, maintenance, and risk of the investment. Dairy cows have an average productive lifetime of four years. Since the average cow is in its second year of production, it has two productive years remaining. This requires a 50 percent return on the livestock investment, but the salvage value of the cows will return a small sum thereby reducing the minimum required return from 50 to approximately 40 percent. The forage investment also requires a 40 percent return for the average alfalfa-brome stand is in good condition for only two to three years. Therefore, the forage investment must return enough money to pay for the cost of establishing new stands and to be able to absorb losses of new seedings or drought. The livestock-forage investment of $7,227 is highly productive on the experimental township farms and should be expanded for the marginal value product exceeds the marginal factor cost.

The MVP for the livestock-forage investment in the control township farms returned 81 percent which indicates that the investment was highly productive during the year. Since the investment had a high intercorrelation with machinery it may be overestimating the return to the livestock-forage investment and underestimating the return for machinery. It appears profitable for the control township farmers to expand their livestock-forage investment.

It appears that the experimental township had a more efficient livestock-forage program than the control townships for its 47 percant return is close to equating the marginal factor cost of 40 percent. However, due to high correlations between land, machinery, and livestock-forage, it appears that the return for livestock-forage is overestimated in the control township and that in reality the actual return is less than the estimated 81 percent.

Machinery investment. The MVP for machinery investment on the experimental farms was 24 percent. The minimum expected returns for machinery are about 20 percent as they must be large enough to cover repairs, depreciation, and maintenance.

The machinery investment of $6,059 for the control township area earned 31 percent on the investment during the year. The machinery investment had a high correlation with land and livestock-forage thereby causing biases to enter into the estimates, hence, making it difficult to predict the actual return to the machinery investment.

It appears that there is little difference in the level of efficiency for the machinery investment in the two townships. The experimental township return of 24 percent compared to a 31 percent control township return indicates that they are both close to equating their machinery investment MVP with the marginal factor cost of 20 percent.

Labor, land, and livestock-forage input. The high intercorrelations between land and labor, between machinery investment and livestock-forage investment caused considerable bias to exist in the returns to the control township. As it was pointed out in Chapter II, high intercorrelation between input categories can cause unreliable marginal value product estimates by overestimating one input while underestimating another input. It was believed that livestock-forage was overestimated while land was underestimated in the control township.

Since additional observations were not available for the control township to increase the n and thereby reduce biases between land, labor, and livestock-forage, the three inputs were combined into one input. The combined marginal value product of one month of labor plus the mean proportion of land and livestock-forage investment will make it possible to compare the combined earning power of the three inputs in the control township with the same combination of inputs in the experimental township. The process of combining inputs is called taking a "partial total" derivative of gross income with respect to the combined inputs.[1] The term derivative is used to express algebraically the relationship between output or Y and an input X. Consider the total derivative of $\frac{dY}{dX_2}$. The equation shows how the output Y changes when the input X_2 changes, the other inputs varying in some degree. The algebraic expression for the partial derivative is $\frac{\partial Y}{\partial X_1}$. A partial derivative measures the small change in Y resulting from a small change in X_1 as that change goes to zero, all other inputs held constant. The following example illustrates how to take a "partial total" derivative. Suppose that the inputs X_i and X_j are so highly correlated that σ_{bi} and σ_{bj} reduce significantly the value of bi and bj and that the σ_{bi} and σ_{bj} cannot be reduced. The "partial total" derivative equation is as follows:

$$\frac{\partial Y}{\partial X_i} \frac{\partial Y}{\partial X_j} = \frac{b_i Y}{X_i} \frac{dX_i}{dX_i} + \frac{b_j Y}{X_j} \frac{dX_j}{dX_i}$$

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[1]Johnson, "The Cobb-Douglas Production Function with Special Reference to Fitting Value Productivity Functions," op. cit., p. 20.

Since a partial derivative assumes that the remaining inputs other than the ones studied are constant, these assumptions also hold true in this case: 1) that the X's which are not X_i and X_j are constant, and 2) that X_j varies with X_i in the proportions in which they are observed to vary among the farms sampled. The resulting MVP is one of a MVP of a unit of X_i plus that amount of X_j observed to be used with a unit of X_i.

In order to apply this equation to the control township function, it is first necessary to state the inputs that will be combined. The "partial total" equation will be used in the control and experimental townships to combine labor, land, and livestock-forage into a new input. The resulting combined marginal value products for the two townships will be compared to see if there is any difference in the combined earning power of these inputs in the two townships.[2] The means and MVP's of the inputs appear in Table 13.

TABLE 13

COMPARISON OF GEOMETRIC MEANS AND MARGINAL VALUE PRODUCTS FOR LAND, LABOR, AND LIVESTOCK-FORAGE IN THE EXPERIMENTAL AND CONTROL TOWNSHIPS, 1953

Input Category		Geometric Mean		Marginal Value Product	
		Control	Experimental	Control	Experimental
Land	X_2	149.8	142.1	$-1.89	$21.33
Labor	X_3	16.81	18.35	$123.42	$91.24
Livestock-forage	X_5	$7,644.	$7,227.	.81	.47

[2] If these three inputs were used to refit a new function it is probable that the resulting combined MVP of the three inputs would not be the same as the value derived by taking a "partial total" derivative.

Substituting the geometric mean values of X_2, X_3, and X_5 plus the MVP's of X_2, X_3, and X_5 in the control township equation gives the MVP of labor plus land and livestock-forage as follows:

$$\frac{dX_1}{dX_3} + \frac{dX_1}{dX_2}\ \frac{dX_1}{dX_5} = \frac{X_1}{X_2}\ \frac{dX_2}{dX_3} + \frac{X_1}{X_3}\ \frac{\text{differential } X_3}{\text{differential } X_3} + \frac{X_1}{X_5}\ \frac{dX_5}{dX_3}$$

$$MVP\ X_3X_2X_5 = \$-1.89 \left[\frac{149.8}{16.81}\right] + \$123.42\ [1] + .81 \left[\frac{\$7,644}{16.81}\right]$$

$$= \$-1.89 \times \$8.91 + \$123.42 + .81 \times \$454.72$$

$$= \$-16.83 + \$123.42 + \$368.32$$

$$MVP\ X_3X_2X_5 = \$474.91$$

The MVP $X_3X_2X_5$ represents the earning power of a month of labor plus the earning power of land and livestock forage investment combined in geometric mean proportions for the control township.

Substituting the experimental township values into the equation gives the following results:

$$\frac{dX_1}{dX_3} + \frac{dX_1}{dX_2} + \frac{dX_1}{dX_5} = \frac{X_1}{X_2}\ \frac{dX_2}{dX_3} + \frac{X_1}{X_3}\ \frac{\text{differential } X_3}{\text{differential } X_3} + \frac{X_1}{X_5}\ \frac{dX_5}{dX_3}$$

$$= \$21.33 \left[\frac{142.1}{18.35}\right] + \$91.24\ [1] + .47 \left[\frac{\$7,227}{18.35}\right]$$

$$= \$21.33 \times \$7.74 + \$91.24 + .47 \times \$393.84$$

$$= \$165.09 + \$91.24 + \$185.10$$

$$MVP\ X_3X_2X_5 = \$441.43$$

The combined earning power of labor, land, and livestock-forage of $474.91 in the control township compared to $441.43 in the experimental township indicates that the two townships have almost identical earning powers for these inputs. This comparison and the individual marginal value product comparisons previously made in this section indicates that when the two townships marginal value products are compared on the basis of judgment and three inputs with high correlations are combined into one input there is little difference in the level of economic efficiency in the two townships for the benchmark year of 1953.

Statistical Tests Used to Compare Production Functions and Regression Coefficients for the Experimental and Control Townships

The purpose of this section is to present the results of various statistical tests that were used to determine whether the experimental township had the same or a different level of economic efficiency than the control township function for the benchmark year of 1953.

Comparison of the slopes of the production function. As it was previously discussed in Chapter II, the sum of the regression coefficients in Cobb-Douglas analysis indicates whether increasing, constant, or decreasing returns to sale exist depending upon whether the $\sum$bi's is greater than, equal to, or less than one. In order to determine whether the $\sum$bi's are greater (smaller) than one, a test is required that will determine whether the sum of the regression coefficients in a particular sample is significantly different from one.

Olkin of Michigan State University, developed a test using the F-statistics which permits statistical testing of the sum of the regression coefficients against any constant C.[3] This test as well as the computations adapted to the Doolittle method are presented in Appendix B.

The test has been carried out for both the experimental township and control township functions, the sum of the regression coefficients being tested against one. For the experimental and control township functions the $\sum bi$ was not significantly different from one. Thus, it is concluded that constant returns to scale prevail for the experimental and control township functions for the benchmark year of 1953.

In order to determine if the sum of the regression coefficients for the experimental township function was significantly different from the control township function the $\sum bi$ of the experimental township (1.195529) was tested against the $\sum bi$ of the control township (1.231925) function. The results of the test revealed that the slope of the two functions was not significantly different from each other for the benchmark year.

<u>Comparison of the individual regression coefficients</u>. Confidence limits cannot be attached to marginal value product estimates because of the lack of a measure of the variation of the expected gross income in the MVP equation MVP $X_i = \frac{bi\ E\ (Y)}{X_i}$. Therefore, if each

[3] Ingram Olkin, "Unpublished report about a problem in testing sums of regression coefficients of linear multiple regression lines against a constant." This report has been made by the statistical group of the Mathematics Department to Professor Glenn L. Johnson, Department of Agricultural Economics, Michigan State University.

individual regression coefficient for the experimental township were compared with the corresponding regression coefficient for the control township, it can be determined if the regression coefficient for the township is the same or significantly different from the regression coefficient for the experimental township. Hannan at Michigan State University, suggested a t test for this comparison.[4] The test as well as the mechanics for carrying it out are presented in Table 14.

The test has been carried out for each of the five regression coefficients b_2 - b_6. When the individual regression coefficients were compared with the $t_{(.95)}$ level = 2.00 none of them, as shown in Table 14 were found to be significantly different from each other. Thus, it can be concluded that for the benchmark year of 1953 the individual estimated regression coefficients in the experimental township were not significantly different from the estimated regression coefficients in the control township function.

Comparison of the aggregate regression coefficients for the experimental and control township functions. The purpose of this section is to determine if the totality of the regression coefficients for the experimental township function were significantly different from the control township function for the benchmark year of 1953. The procedure followed was to estimate the expected gross income for each farm in the experimental and control townships by using their respective sets of regression coefficients and the quantities

[4] Statement by James F. Hannan, Assistant Professor of Statistics, Michigan State University, personal interview.

TABLE 14

COMPARISON OF INDIVIDUAL REGRESSION COEFFICIENTS FOR THE EXPERIMENTAL TOWNSHIP FUNCTION WITH THE CONTROL TOWNSHIP FUNCTION, 1953

Input	Regression Coefficient		Difference	Standard Error		t Value*
	Experimental bi	Control bi'	bi-bi'	Experimental bi	Control bi'	
Land	.289740	-.025361	.315101	.126122	.106929	1.71
Labor	.160090	.186111	.026021	.118746	.096064	.06
Expenses	.284260	.348558	.064298	.122984	.072420	.54
Livestock-forage	.322018	.556546	.234528	.128456	.094148	.68
Machinery	.139422	.166067	.026645	.141520	.082293	.06

$$* \; t = \frac{bi - bi'}{\sqrt{\Sigma C_{ij} + \Sigma C_{ij}'}\sqrt{\dfrac{\sigma bi^2(n-1) + \sigma bi'^2(n_2-1)}{N_1 + N_2 \quad -2}}}$$

of inputs actually employed on each surveyed farm for 1953. For example the expected gross income for farm number one in the experimental township is shown in Table 15.

TABLE 15

ESTIMATED GROSS INCOME FOR A FARM IN THE EXPERIMENTAL TOWNSHIP, 1953

Input Category	Amount Used	Logarithm of Amount Used	Regression Coefficient	Regression Coefficient x Logarithm of Amount Used
Land	117	2.06819	.28974	.59923
Labor	10	1.00000	.16009	.16009
Expenses	$2,547	3.40603	.28426	.96819
Livestock-forage	$5,102	3.70774	.32202	1.21639
Machinery	$4,132	3.61616	.13942	.50416
Constant (a)				.42449
Total				3.85015
Gross Income				$7,082

The antilog of 3.85015 is $7,082, the estimated gross income for the farm as compared to the actual gross income of $6,820 reported on the survey schedule. The next step is to determine the expected gross income for this farm by using the control township regression coefficients and the actual quantities of inputs used on the farm. The expected gross income thus computed is $6,812. The difference between the two expected gross incomes is taken and the procedure is repeated for each farm in the experimental township. The expected gross incomes are compared for each farm in the control township. The experimental township bi's are substituted into the estimating equation for each control township farm and the gross income for each farm is estimated. The means of the gross income are compared to determine if there is any difference in the estimated gross income for the experimental and control townships when their regression coefficients are substituted. The basic principle of this method is to see if the estimated gross income for the experimental township is as accurate by using the control township bi's as it would be by using the experimental township bi's.

The mean gross income of the experimental township was $11,495 compared to a mean gross income of $11,885 when the control bi's were used to estimate the gross income. The mean difference in the two expected gross incomes was $390. The equation used to test the two means is

$$t = \frac{\bar{x} \frac{n(n-1)}{2}}{S\, X}$$ [5]

This test and the computations for the two townships are outlined in Appendix C. The t values of the two means for the experimental township is .1198 compared to $t_{(.95)} = 1.9976$, so it is concluded that there is no significant difference in the regression coefficients for estimating the gross income in the experimental township.

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[5] George W. Snedecor, Statistical Methods, (Ames, Iowa: The Iowa State College Press, 1950), p. 77.

The same procedure was followed for the control township with the control township bi's yielding an estimated mean gross income of \$11,664 compared to the experimental township bi's yielding a mean gross income of \$11,676 for the control township or a difference of only \$11. The t value of the two mean gross incomes for the control township was .003629 compared to t = (.95) = 2.0016. Therefore, it is concluded that there is no significant difference in the experimental or control township regression coefficients for estimating the gross income in the control township. On the basis of this test, it is concluded that for the bench mark year of 1953, the regression coefficients derived from the sample of 30 control township farms were not significantly different from the regression coefficients derived from the sample of 33 farms in the experimental township.

Comparison of the combined input earning power for the two townships. It was pointed out in the first section of this chapter that some of the individual regression coefficients for the control township were unreliable, thus it was necessary to combine three inputs of land, labor, and livestock-forage investment into one input category. The $MVP_{X\ 325}$ in the experimental township was \$441.43 and the control MVP_{X325} was \$474.91. Thus it is concluded that there is little difference in the level of efficiency of these three inputs in the two townships.

Summary of the Statistical Tests

The purpose of developing and using statistical tests to compare the two functions has been to determine if the level of economic efficiency in the two functions were the same or different from each other for the benchmark year of 1953. The following tests have been used to compare the two functions. The sum of the regression coefficients for each township, although larger than one, were found to be not significantly different from one or different from each other by the use of Olkin's equation. The individual regression coefficients in each function were tested against the coefficients in the other function by the use of a t test. No significant difference was found in any of the coefficients for the two townships. The aggregate effect of interchanging the regression coefficients for the two townships to estimate gross income was tested by a t test of the means of the expected gross income. The results of the t test reveal no significant difference in the regression coefficients for the two functions in the benchmark year. Since some difficulty in interpreting the marginal value products existed due to high inter-correlations existing in the control township, three of the inputs, land, labor, and livestock-forage were combined into one input. The results indicate that the earning power for the last month of labor plus the mean proportions of land and livestock-forage investment was within a few dollars of each other in the two functions. Thus it is concluded that little difference in the earning

power and the level of efficiency of labor, land, and livestock-forage existed for the two functions. The MVP's of expenses and machinery for the two functions were within a close range of each other; it was concluded that the level of efficiency for these two inputs was about the same. On the basis of these statistical tests and judgment, it is concluded that the level of efficiency in the two functions was not significantly different from each other for the benchmark year of 1953.

Evaluating the Changes in Economic Efficiency on the Basis of Cobb-Douglas Analysis at the Completion of the Township Extension Experiment

The same method of using Cobb-Douglas analysis to establish a benchmark of efficiency in the experimental and control township in this study was used to establish benchmark levels of economic efficiency in the other four experimental and their matching control townships for 1953. Terminal surveys on the same 400 benchmark farms in the experimental and control townships will be made in early 1959 in order to collect information on the 1958 farm business year. This data will be used to fit Cobb-Douglas functions in each of the five experimental and five control townships. A terminal level of efficiency will be determined on the basis of the fitted functions. The change in efficiency in each of the townships during the five-year experiment will then be computed.

The purpose of this section is to discuss some of the possible methods that might be used to measure the changes in efficiency on the basis of Cobb-Douglas estimates of 1953, and 1958.

Changes in Terminal Survey Schedule

While these recommendations are not based on an appraisal of each of the other four experimental and four control township results for the benchmark year, it will draw from the experience of the writer in collecting some of the data in the control township and fitting functions to one experimental and its matching control township. The first recommendation is to value the dairy portion of the livestock investment on the average milk production of each herd, rather than having the farmer or interviewer value the herd. The need for this change is based on the necessity of revaluing the dairy herd in the control township and fitting a new function in this study. The only other minor suggestion is to alphabetize the machinery and equipment items to save time during the interview. The expense page could be altered slightly so that the expenses used in Cobb-Douglas analysis are listed in a separate column.

Collecting the Data

The major suggestion for collecting the data is to plot the quantities of inputs and investment used on each new farm surveyed in order that a wide range in the quantities of inputs can be selected. This recommendation will have to fit in with the pairing procedure followed in the benchmark study, for the same farms surveyed in 1953 will also be resurveyed in 1958. This procedure could be used to select replacements for farmers interviewed in 1953 but who have quit farming, refused to be reinterviewed, or for those schedules that were unusable for benchmark analysis. Eight of the 40 control township schedules and five of the experimental schedules were unusable in this study. As an example, several fruit farms surveyed in 1953 in the control township offered little information about dairying, hence these farms could be replaced by dairy farms in the terminal survey.

Fitting the Functions

The only change involved in fitting functions to the terminal data is to adjust the 1958 prices to the 1953 level in order that the effects of inflation or deflation will not enter the estimates. Thus, the changes in efficiency will reflect the changes in the quantities and combinations of inputs used rather than the influence of price changes.

Comparing the Terminal Estimates with the Benchmark Estimates

The objective of this procedure is to determine the changes in economic efficiency that have occurred during the five-year experiment. The first step involves comparing the terminal experimental township functions with their base year functions and similarly for the control townships. The changes in efficiency that have occurred in the experimental townships will be attributed to the township agent, and the control township changes will be attributed to the regular county extension program. If the efficiency changes are greater for the experimental townships than their corresponding control townships, this increase will be attributed to the township extension agent. However, if the control township changes are greater or not significantly different from the experimental township changes, then it will be concluded that the township extension program was of no greater value in changing the level of efficiency than the traditional county extension program. One of the hypotheses of the total township program was to determine if the township agents could speed up the technology in the township areas faster than the county extension agents could do in their county areas. Technology change is one of the factors responsible for a change in efficiency.

Two major factors leading to efficiency changes are a change in technology and a shift in farm organization. A technology change occurs when the same quantity or fewer inputs cause an increase in gross income. For example, if farmers increase their gross income during the five-year experiment by using the same quantities of inputs as in 1953, but improved seeds, feeds, and breeding practices cause the gross income to increase, then the increase in gross income is attributed to technology change. The second factor, a shift in farm organization, occurs when input substitution causes a change in gross income. For example a change in gross income from the use of more machinery and less labor is attributed to a change in the farm organization.

This section will discuss several proposals for measuring these two factors that might be responsible for changes in efficiency on the farms during the experiment. The first test is to determine if there has been a change in the production functions by a technology change.

Technology change. For example the 1953 function is derived from the mean organization of inputs and investments used in the production process during that year as follows: $Y = a X_1^{b_1} \ldots . X_6^{b_6}$. The 1953 function yields an estimated regression curve labled 1953 as shown in Figure V.

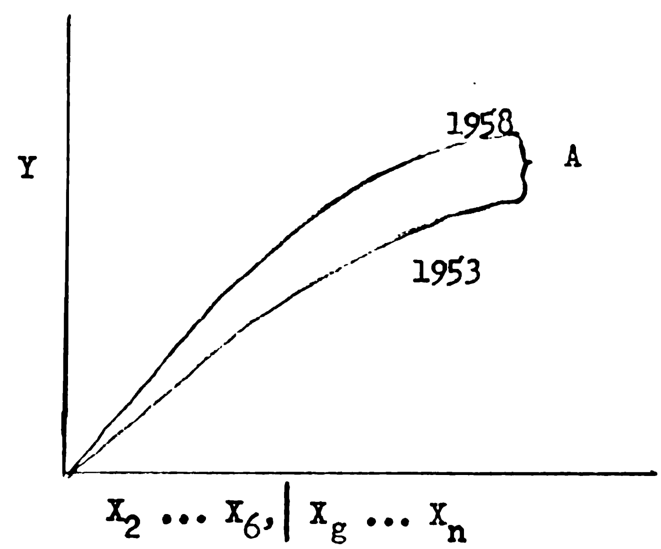

FIGURE V. Change in Economic Efficiency Resulting from a Technology Change During 1953-1958.

By substituting the 1953 mean organization into the 1958 equation (in 1953 dollars), it will be possible to determine the regression curve that will result from using the 1958 regression coefficients and the 1953 mean quantities of inputs. The resulting 1958 regression curve is shown in Figure V. If the 1958 production function is significantly different from the 1953 production function, then it may be concluded that there has been a shift in the production function or a change in the technology. This change is labeled A in Figure V. The change in technology is credited to the township agent in the experimental townships and to the county extension organization in the control townships. If the change in technology in the experimental township is significantly greater than the control township change, then it is concluded that the township agent increased the rate of technology faster in a township area than the county extension organization did in a county area during the five year period.

While the total changes in efficiency for each township are useful for evaluation much insight can be gained by analyzing the changes in efficiency on the individual farm basis. A suggested method of computing the changes in economic efficiency on the individual farm basis are suggested by Glenn L. Johnson as follows:

1. Deflate or inflate 1958 input data to 1953 price levels for each farm.
2. Deflate 1958 gross income to 1953 levels for each farm.
3. Estimate income from 1953 function using 1958 deflated input data.
4. Find proportion of positive deviations of 1958 gross income from 1953 gross income.
5. Test with binomial against p=50.
6. If significantly>50, a technological advance has occurred.[6]

<u>Farm organization change</u>. A shift in farm organization is also responsible for a change in economic efficiency. For example consider a situation when the base year MVP of labor is $91, machinery is 41 percent and the terminal year MVP of labor is $148 and the machinery investment is 26 percent. On the basis of these estimates it is concluded that the 1958 farms are more efficient because their MVP's are closer to their marginal factor costs of $150 for labor and 20 percent for machinery. The increase in the efficiency might have been caused by using more machinery and less labor. An example of such a shift

[6] Statement by Glenn L. Johnson, personal interview.

in farm organization is illustrated in Figure VI. The machinery investment for 1953 is shown as point A and the 1958 investment as point B.

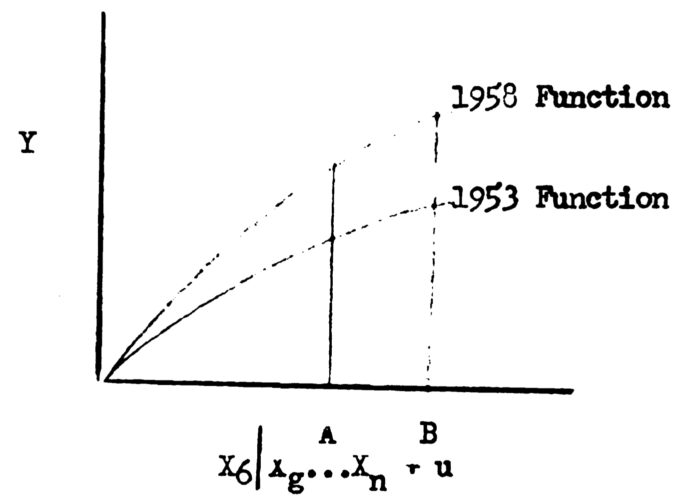

FIGURE VI. Change in Economic Efficiency by A Shift in Farm Organization. Increasing X_6 from A in 1953 to B in 1958.

Thus the researcher can isolate the technology and farm organization changes and measure their impact on the efficiency changes at the completion of the experiment.

Other Suggested Statistical Tests

Several statistical tests used to compare the levels of efficiency in this study are also suggested for use in evaluating the terminal results. These are: Olkin's test of the $\sum$ bi's against one, the experimental township $\sum$ bi's against the $\sum$ bi's of the control township; Hannan's t test of the individual bi's of the experimental township against the control township, and use of the t test of the means of gross income to see how close the estimated mean gross income is for each experimental and control township when their bi's are interchanged.

While these tests are not all-inclusive, they perhaps will provide a guide for the project evaluator to follow in evaluating the changes in economic efficiency at the completion of the experiment in 1958.

Determining Why Efficiency Changes Occurred

After the changes in economic efficiency have been computed and the experimental townships' changes are compared with the control townships', it will be of interest to determine why some of these changes might have occurred other than the two major reasons of technology change and farm organization change. A factor to consider is the effect of inefficient farmers surveyed in the benchmark year who shift enterprises or quit farming. If ten of the 38 dairy farms in the experimental township change from dairy to beef production these ten might be replaced by more efficient dairy farms for the terminal survey. What effect will this change have on the efficiency level for the sample? Supposedly, the control and experimental farmers changing enterprises during the five-year period will counterbalance each other, but in the experimental township, the township agent is working closely with a small number of farmers while in the control township, farmers compete with 3000 other farmers for assistance from the county extension service. If a larger percentage of the dairy farmers in the experimental township are still in the dairy business after the five-year experiment than the control township, then it might be concluded that the township agent was responsible for helping the dairy farmers adopt more efficient production processes so they could stay in business.

Appraisal of Cobb-Douglas Analysis as a Measure of Economic Efficiency

It is felt that both traditional farm management techniques and production function analyses can make a contribution in the field of farm management. Both old and new approaches are useful in measuring economic efficiency; both require interpretation based on statistical tests and sound judgment. The purpose of this section is to appraise the use of one of the new approaches in production function analysis that of Cobb-Douglas analysis as a measure of economic efficiency.

Advantages of Cobb-Douglas Analysis

Both the advantages and limitations of Cobb-Douglas analysis will be discussed under the framework of measuring economic efficiency. The special advantages and limitations of its use in extension evaluation will be covered in Chapter V. The ease of estimating the regression coefficients by ordinary least-squares regression methods after transforming the data into logarithms is one of the main advantages of using Cobb-Douglas analysis. In addition this technique yields estimates of marginal productivities for individual categories of inputs and investments. Another advantage of Cobb-Douglas analysis is that it yields estimates with greater degrees of freedom for a small sample than other techniques permit.

Limitations of Cobb-Douglas Analysis

The limitations of this type of analysis can be presented under three categories: inherent characteristics of the function itself, accounting problems of both inputs and gross income, and unmeasured variables.

Inherent characteristics of the function. The important shortcomings of the function itself are: 1) the function is limited to handle relationships for firms in only one stage of production at a time because the coefficients of elasticity are constant over the entire range of the function, 2) the function always originates at $Y = X_1 = 0$ and in addition if any $X_i = 0$, then $Y = 0$, and 3) symmetry of the function implies that there is an unlimited range in which the proportion of any two inputs could be used to produce a given level of output.[7]

Accounting problems. Accounting problems in Cobb-Douglas analysis center around measuring inputs, and measuring gross income.

One of the first problems involved in measuring input categories is that of establishing a procedure of defining or setting up the categories. In Cobb-Douglas analysis the Xi usually refers to a group of inputs instead of a single input. For example labor inputs represent a combination of hired, family, and the operators labor while the land input includes rented and owned land. The collective land input also includes all land that is used in the farming operation regardless of whether it is being used in row crops, legumes, or in

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[7] Carter, *op. cit.*, pp. 11-14.

summer fallow. The basic question which arises when setting up input categories is, "is there an ideal method of grouping individual inputs into categories?" The preferred method states that all inputs grouped together should meet the least-cost combination.[8]

There is no set procedure in measuring categories of inputs that has been established, but the general rules that are suggested by Glenn L. Johnson[9] offer a good guide to follow. The important factors involved in measuring inputs are those of establishing a standardized system for handling many of the subjective factors and then maintaining a consistent pattern throughout the entire study.

The accounting problems which arise when measuring gross income are those of combining the products of one or more enterprises into the value product for the whole farm and reflecting changes in inventory resulting from various investments and expenditures made during the year.[10]

Multiple enterprises within a farm business can be combined into a single measure of gross income for the farm by restricting the sample under study to farms having one major enterprise or by fitting a separate production function for each enterprise. A physical cost

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[8]A least-cost combination refers to the best way to spend a given amount of money on all pairs of inputs in order to produce any given output .

[9]Bradford and Johnson, op. cit., p. 144.

[10]Johnson, "The Cobb-Douglas Production Function with Special Reference to Fitting Value Productivity Function for Farm Businesses," op. cit., p. 31.

accounting system for handling multiple enterprises has been recently developed by Beringer.[11]

The second major accounting problem encountered in measuring gross income is that of handling depreciation, maintenance, and repairs in inventory changes. The difficulty of adjusting gross income arises since these items do not help generate gross income but rather, they protect the value of the fixed assets. The most accurate method for handling all items that do not help generate gross income is to eliminate them from the input categories.[12] For example, by eliminating these items from the machinery investment, the marginal return to the machinery investment must be large enough to cover repairs, maintenance, and/or depreciation as well as whatever return the manager considers necessary.

Unmeasured variables. Certain important factors in the production process are difficult to define, record, and measure. These unmeasured variables include intangible and subjective factors such as management, weather, and technology. There are two methods of handling these factors (1) design study to hold these factors constant or to a non-troublesome range or (2) measure unexplained residuals and incorporate them into the study.[13]

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[11] Christoph Beringer, "A Method of Estimating Marginal Value Productivities of Input and Investment Categories on Multiple Enterprise Farms," (Unpublished Ph. D., Dissertation, Department of Agricultural Economics, Michigan State University, 1955).

[12] Johnson, "The Cobb-Douglas Production Function with Special Reference to Fitting Value Productivity Functions to Agriculture," op. cit., p. 34.

[13] Ibid., p. 26.

The most important of these factors, management, is usually unmeasured in value productivity studies because of the difficulty in defining and measuring it. The most practical method of handling management in view of this is to use personal judgment based on existing managerial concepts when selecting farm managers for the sample. This procedure attempts to restrict the farms in a sample to a range with respect to managerial capacity so that all farms will be operating on the same managerial production function. A further refinement can be made by examining surveys with large unexplained residuals; if these can be attributed to superior or inferior managers omitting or replacing these surveys will then more closely satisfy the condition that all farms will be on the same managerial production function.

Comparison of Cobb-Douglas Analysis With the Essential Characteristics of a Good Measure of Economic Efficiency

In Chapter I the characteristic of reliability and validity were suggested as being necessary for a good measure of economic efficiency. The purpose of this section is to compare the characteristics of Cobb-Douglas analysis on the basis of this study with these essential characteristics. It must be realized that some of the details of using this method cannot be fully appraised until the completion of the experiment.

Validity. The characteristic of validity stated that the measure must reveal the level of economic efficiency for the firm. In order to meet this condition the output must be measured in marginal terms and both input and output must be measured. Cobb-Douglas analysis meets the validity condition by providing an estimate of the level of efficiency for a sample of farms by estimating marginal value productivities of inputs and investments. These estimates can be compared with the marginal factor costs for each input and the level of efficiency for the sample can be derived. The optimum level of efficiency is derived by the marginal factor costs for each measured input and investment. Both input and output are measured in Cobb-Douglas analysis. The output is measured in marginal terms.

Reliability. The condition of reliability is met when a measure can be used by the same or different researcher in the same sample area or different sections of the county to derive approximately the same estimates of productivity.

The reliability of Cobb-Douglas analysis is dependent upon many factors such as the sampling procedure employed, the accuracy of grouping of inputs, and the statistical tests used. This type of analysis is subject to many of the common problems of conducting any type of empirical research in agriculture, hence many of its shortcomings are common to other types of production function analysis.

On the basis of fitting this type of function to two townships in this study it is felt that the experimental township results were highly reliable while some of the shortcomings in the sampling techniques caused only fairly reliable control township estimates. In the control township the high intercorrelations caused several unreliable marginal value products. It is felt that under new sampling procedures in which a wider range in inputs were selected, more reliable control township results could be obtained. Some of the important factors affecting the reliability of this type of analysis were discussed in Chapter II. On the basis of this study and similar studies conducted across the country such as the Northern Iowa, Southern Iowa, Montana and Alabama study of resource productivity it appears that Cobb-Douglas analysis can be used to measure economic efficiency in different parts of the country and for different types of farming.[14]

Summarizing the results of comparing Cobb-Douglas analysis on the basis of the experienced gained in this study with the necessary prerequisites of a good measure of economic efficiency reveals the following: it satisfies the validity characteristic, measures both input and output, output is expressed in marginal terms, while the reliability characteristic was not fulfilled in the control township hence this characteristic cannot be fully appraised until the completion of the experiment.

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[14] Earl O. Heady and Russell Shaw, Resource Returns and Productivity Coefficients in Selected Farming Areas of Iowa, Montana, and Alabama, Research Bulletin 425, Iowa State College, Ames, Iowa, April, 1955.

CHAPTER V

APPRAISAL OF COBB-DOUGLAS ANALYSIS AS A TOOL OF EXTENSION EVALUATION

This chapter appraises the use of Cobb-Douglas analysis in extension evaluation on the basis of using this method to establish benchmark levels of economic efficiency in one of the experimental and its matched control township for this thesis study.

Economic Efficiency Redefined

One of the major tasks of farming is to organize limited resources into the most profitable operating unit. A farmer faces many alternative uses for his capital and labor. With limited funds the farmer must invest these where they will yield the greatest return. If this condition is followed, the returns for the farm firm will be maximized. While farmers use their own knowledge to solve many of the managerial decisions leading towards profit maximization, they have an opportunity to obtain advice from local county extension agents, township extension agents, college specialists, commercial management firms, and to obtain educational information from feed or seed dealers and other agencies. Since farmers request information from the county extension agents and even more intensive assistance from the township extension agents in order to achieve greater economic efficiency, one of the methods used to evaluate the township program is a measure of economic efficiency.

Cobb-Douglas analysis is used along with traditional farm management analysis to measure the changes in economic efficiency which occur as a result of the township extension program. Using the strong points of both methods of analysis will enable an evaluation procedure to be developed to record, measure, and interpret the changes in economic efficiency resulting from the township program.

Methodological Procedures

While the general nature of setting up a Cobb-Douglas problem was outlined in Chapter II, this section will cover some observations gained from surveying some of the farms in the control township and fitting functions to both townships.

Sampling

A major decision facing extension evaluators who are measuring economic efficiency is the type of sampling method to employ. A discussion of the three types of sampling--farm record-keeping projects, random, and purposive was presented in Chapter II. Purposive sampling was selected for this study in order to reduce the intercorrelation between the input categories and thus increase the reliability of the bi's and the MVP estimates. It is realized that by using purposive sampling in this study to select a small number of farms that only one type of farming is analyzed. Restricting the sample to one type of farming has been questioned by some extension evaluators. Evaluators want to know what changes occur in all types of farming as a result of extension education rather than to have specific information on one type of farming. This is a problem faced in this study which is important not only in Michigan but in other states with a diversified agriculture.

Several alternatives are available for an evaluator who wishes to employ purposive sampling and still gain information on all types of farming in the area. A large random sample of 100-200 farms can be drawn (this was impossible in a six square mile township area in this study as there were only 100-160 farms per township) and several subsamples of 25-30 schedules of dairy, beef, or fruit farms could be used to fit dairy, beef or fruit functions. Another alternative is to select a small sample of 25-40 farms purposively and then use Beringer's multiple enterprise Cobb-Douglas function to fit both crop, hog, dairy, or beef functions. In view of the cost of collecting data it appears that purposive sampling does have an important contribution to make in sampling for extension evaluation as it permits small samples of 30-40 schedules compared to several hundred as commonly collected by random sampling methods.

Cost

The cost and benefit of any method of collecting and analyzing information for making estimates of resource productivity is of great importance to extension administrators and evaluators. Currently, extension administrators in several states are in the process of evaluating their farm and home development programs. Several states are examining the possibilities of using Cobb-Douglas analysis as a tool of evaluation.

Although no detailed cost studies have been made on using Cobb-Douglas analysis, it is estimated that the benchmark study cost per processed schedule was $30 each. This is broken down into approximately $20 field cost and $10 statistical processing cost. At a cost of $30 each, the total cost of the 78 schedules for this study would be approximately $2,340. This compares with approximately $25 per schedule in the Michigan farm account project of over 500 farms. Glenn L. Johnson, while at the University of Kentucky, conducted several Cobb-Douglas studies and estimated a $25 cost per completed processed schedule in 1952.

The $30 cost per schedule for this study included not only information necessary for Cobb-Douglas analysis but also such items as changes in farm practices, net worth, extension participation, and traditional farm account information. Consequently the cost per schedule for Cobb-Douglas analysis is under $30 if proportional credit is allowed for the information collected other than for Cobb-Douglas analysis.

Accounting

Glenn L. Johnson has stated frequently that accurate Cobb-Douglas analysis depends upon a sound knowledge of basic farm accounting. This statement, is important because the accuracy of grouping inputs, collecting the data, and interpreting the results all center around a knowledge of farm accounting. The problems encountered in accounting for both inputs and gross income are discussed in Chapter IV. These problems and developing statistical tests were the two most difficult aspects of this study.

Fitting the Function

Three functions had to be fitted to the control data because of a failure in the sampling procedure to first select a wide range in the quantity of inputs and investments. Another error in the control data was undervaluing the dairy herd which caused an overestimated MVP of the livestock-forage investment. Because of such errors, it may be necessary to refit functions to insure accurate results.

Price Change Adjustments

Formerly Cobb-Douglas results held from year to year only if the prices of input and output increased (decreased) proportionately or remained the same. However this situation has been recently corrected by Trant's method of adjusting prices of input and output by Laspeyre's index. Thus it is possible to adjust Cobb-Douglas estimates to price changes and extend the useful life of the estimates. It is concluded tentatively that this method can be adopted for the 1958 terminal data.

Interpretation

Many factors are involved in interpreting the results of Cobb-Douglas analysis. The use of sound judgment based on a thorough knowledge of the area under study, basic accounting procedures, and knowledge of marginal analyses are important to the success of this type of analysis.

Application

Although the Cobb-Douglas method was used previously in agricultural studies, it still remains to be widely used for estimating economic efficiency in agriculture. An obstacle is that the results of Cobb-Douglas studies are limited to the specific type of farming and geographic area studied. For example, the results of this study will provide a framework for budgeting and analyzing dairy farms only in the experimental and control townships and surrounding areas. Extension evaluators have hesitated to use the method for a variety of sound reasons. Among these are the lack of information about the procedure involved in adapting this type of analysis to extension evaluation, and the questionable reliability of the method.

Summary

On the basis of this preliminary study, the following highlights of the potential use of this method in extension evaluation are:

1) It satisfies the condition of validity.
2) Its reliability is somewhat questionable on the basis of the control township's results.
3) A sound knowledge of farm accounting is extremely important to the success of Cobb-Douglas analysis.

4) Purposive sampling permits 30-40 schedules to be selected per county or township.

5) The cost of using this method is about $30 per processed schedule.

6) Several statistical tests outlined in Chapter IV offer possibilities for measuring the significance of the levels of efficiency in a sample area.

7) The preliminary results of estimating and comparing benchmark levels of efficiency in two townships suggest that Cobb-Douglas analysis is a good over-all measure of efficiency and is better adapted to measuring the changes in efficiency for a group of farms than on an individual farm basis.

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APPENDICES

APPENDIX A

SURVEY SCHEDULE USED TO COLLECT INFORMATION FROM 200 FARMS IN THE FIVE EXPERIMENTAL TOWNSHIPS AND 200 FARMS IN THE FIVE CONTROL TOWNSHIPS FOR THE YEAR OF 1953

C-O-N-F-I-D-E-N-T-I-A-L

Information on the attached confidential survey form is to be used only for research at Michigan State College.

Farm No. ________ Interviewer ____________

Date of Interview ________

Name ______________________ Address ______________________

County ____________ Twp. ____________ Sect. ____________ Qtr. ________

Location of Farm ______________________________________
(Miles from town)

SIZE OF FARM

Total Acres ____________ Owned ____________ Rented ____________

Tillable Acres ____________ Owned ____________ Rented ____________

Type of Lease ______________________________________

CROPS RAISED

CROP	Acres	Yield		Total Prod. 1953
	1953	1953	1951-53	
Corn for silage				
Corn for grain (sh. bu.)				
Beans				
Potatoes				
Sugar beets				
Oats				
Wheat				
Grass silage				
Legume silage				
Hay: Alfalfa (50%)				
Other legume (50%)				
Nonlegume				
Tillable pasture:				
Alfalfa (50%)				
Other legume (50%)				
Nonlegume				
Green manure crop				
Idle				
Summer fallow				
TOTAL TILLABLE ACRES				
Nontillable pasture				
Woods not pastured				
Farmstead, roads, lanes				
TOTAL ACRES				

FERTILIZER APPLIED IN 1953

Crop	Acres	Kind	Lbs. per acre	Total Lbs.	Price	Cost
Fertilizer: Corn Planting					$	$
Side dress						
Oats, seeded						
Oats, not seeded						
Wheat, '52-53 Seeded At Planting						
Top dress						
Wheat, '52-53 Not Seeded At Planting						
Top dress						
Wheat, '53-54 At Planting						
Hay, Top dress						
TOTAL FERTILIZER	XX	XXX	XXX		XX	

Lbs. of fertilizer per tillable acre ____________

Cost of fertilizer per tillable acre $____________

LIME APPLIED IN 1953

Acres	Tons Per Acre	Total Tons	Price	Cost
________	________	________	$________	$________

Indicate field on which major time and fertilizer investments were made ________

____

SEEDS AND PLANTS

Cost of Perennial Seeds and Plants Used in 1953
(Grasses, Legumes, Fruit)

Kind	Acres Seeded	Lbs. Seeded	Cost or Value 1/
			$
TOTALS			

1/Include value of seed on hand at beginning of year or raised during year along with note to that affect.

Hay and Pasture Inventory on Jan. 1, 1953, and Amount Plowed Under During the Year

Kind	Acres	Age and Condition	Value Per A.	Total Value	Plowed Under		Prop. Credit
					Month	Green Manure?	
			$	$			$
TOTALS		XXX	XX		XX	XX	$

Inventory of Small Fruit and Fruit Trees, Jan. 1, 1953

Kind	No. of Acres	Value per Unit	Total Value
		$	$
TOTALS		XXX	$

Cost of machinery hired for land reclamation $ __________

LIVESTOCK INVENTORY AND BALANCE

Kind	Jan. 1, 1953		Add		Subtract		Jan. 1, 1954	
	No.	Value	No. Raised	No. Bought	No. Sold & Butchered	No. Died	No.	Value
Dairy Cattle:		$						$
Cows								
Heifers (over 1 yr.)								
Heifers (under 1 yr.)								
Bulls								
Calves (under 1 yr.)								
TOTAL DAIRY								
Beef Cattle:								
Cows								
Heifers (over 1 yr.)								
Heifers (under 1 yr.)								
Calves								
Bulls								
Feeders								
TOTAL BEEF								
Hogs:								
Sows								
Gilts								
Boars								
Feeders								
Pigs								
TOTAL HOGS								
Sheep:								
Ewes								
Rams								
Lambs								
Feeders								
Wool								
TOTAL SHEEP								
Poultry:								
Hens and pullets								
Roosters								
Broilers								
Turkeys								
TOTAL POULTRY								
GRAND TOTALS	XX	$	XXX	XXX	XXX	XX	XX $	

Heifers Freshened:

No.	Month
____	________
____	________
____	________
	________

LIVESTOCK BOUGHT AND SOLD

Livestock Bought During Year					Livestock Sold During Year				
Kind	No.	Date	Cost	Prop. Cost	Kind	No.	Date	Rec'd	Prop. Credit
			$	$				$	$

MACHINERY AND EQUIPMENT BOUGHT AND SOLD IN 1953 1/

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

1/ Carry over to machinery inventory on following page.

MACHINERY AND EQUIPMENT INVENTORY

Item	Auction Value Jan. 1, 1953	Book Value Jan. 1, 1953 or years remaining	Depre-ciation	Book Value Jan. 1, 1954
Auto: Make & Yr. ______ Farm Share ______ %	$	$	$	$
Truck				
Trailer				
Wagons and racks				
Tractor				
Tractor plow				
Tractor disc				
Tractor cultivator				
Harrows				
Roller or cultipacker				
Field cultivator				
Weeder				
Beet or bean cultivator				
Beet lifter or bean puller				
Corn planter				
Corn picker				
Grain drill				
Grain binder				
Combine or threasher				
Mower				
Hay rake				
Hay loader				
Hay baler				
Forage chopper				
Manure spreader				
Manure loader				
Brooder house				
Brooder stove				
Hog house, portable				
Electric fence				
Feed grinder				
Electric motors				
Milking machine				
Milk cooler				
Cream separator				
Cans, pails, etc.				
Small tools				
Totals				

NEW IMPROVEMENTS BUILT DURING 1953 1/

Month	Item	Cost	Estimated Life
-		$	

1/ Carry to improvement inventory below.

VALUE OF LAND AND BUILDINGS

	Market Value January 1, 1953 1/	Market Value January 1, 1954 1/
Owned land and buildings	$	$
Rented land and buildings		

1/ Use same values at beginning and end of year unless acreage has changed.

IMPROVEMENT INVENTORY

	Book Value Jan. 1, 1953	Depreciation	Book Value Jan. 1, 1954
	$	$	$
Residence			
Tenant house			
Dairy barn			
Other barns			
Milk house			
Corncrib			
Granary			
Hog house			
Poultry house			
Machine shed			
Garage			
Silo			
Storage			
Well & water system			
Fencing			
Tiling			
Building material			
TOTALS	$	$	$

BUILDING CAPACITY

If the best combination of livestock were kept for the present buildings and feed storage, how many of each kind of livestock could be housed?

Dairy cows _______ Dairy young stock _________ Beef cows _____________

Feeder cattle __________ Sows ___________ Feeder hogs (100#) _________________

Sheep __________ Laying hens _________ Chicks _________

Other ____

FEED AND CROP INVENTORY

Kind	Jan. 1, 1953			Jan. 1, 1954		
	Quantity	Price	Value	Quantity	Price	Value
Corn, silage		$	$	$	$	$
Corn, grain (shelled bu.)						
Beans						
Sugar beets						
Potatoes						
Oats						
Wheat						
Hay: Alfalfa						
Other legume						
Nonlegume						
Grass silage						
Straw						
Fodder						
Bean pods						
Commercial feeds						
Seed: Annual Crops						
Seed: Grasses and legumes						
Growing Wheat						
TOTALS	XXX	xx	$	XXX	xx	$

Inventory change $ _______

CASH RECEIPTS

Source	Quantity	Price	Amount Received
Livestock and Livestock Products Sold:			
Cattle (page 4)		$	$
Hogs (page 4)			
Sheep (page 4)			
Poultry			
Milk			
Other dairy products			
Eggs			
Wool			
TOTAL LIVESTOCK			
Crops Sold:			
Wheat			
Oats			
Corn			
TOTAL CROPS			
Other Receipts:			
Woodland products			
Custom work or machinery rented			
Agricultural program payments			
Land and pasture rent			
Dividends			
Total Other			
TOTAL CASH RECEIPTS	XXX	XXX	$

Dairy cattle income $________

Beef income ________

Hog income ________

Sheep income ________

Poultry income ________

Total livestock income $________

Crop income ________

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	XXX	XXX	$

LABOR

Operator ______ months; Family ______ months; Hired ______ months; Total ______

No. of men ______

WORK OFF THE FARM

Kind of Work	By Whom	Days	Rate	Amount Received
			$	$
TOTALS	XXX		XXX	

Total income from other nonfarm sources (interest, dividends, rents, oil royalties.)
$______________

CASH EXPENSES

Item	Quantity	Cost
Hired labor		$
Feed purchased		
Seeds and plants purchased - annual		
Seeds and plants purchased - perennial (page 3)		
Custom work or machinery hired		
Supplies purchased		
Machinery repair and maintenance } Farm share		
Gas and oil for farm use (less refund) } only		
Improvement repair and maintenance		
Livestock expense		
Fertilizer and lime (page 2)		
Taxes		
Insurance on property		
Interest		
Electricity (farm share)		
Telephone (farm share)		
Baby chicks purchased		
Other farm expenses		
TOTAL CASH EXPENSE	XXX	$

APPENDIX B

THE F TEST FOR TESTING THE SUM OF THE REGRESSION COEFFICIENTS IN A LINEAR REGRESSION EQUATION AGAINST A CONSTANT

THE F TEST FOR TESTING THE SUM OF THE REGRESSION COEFFICIENTS IN A LINEAR REGRESSION EQUATION AGAINST A CONSTANT

The following is a method of testing the sum of the regression coefficients of a regression line against a constant. The test was developed by Dr. Ingram Olkin, Associate Professor of Statistics at Michigan State University. The test is applicable in all fitting procedures which use an (n-1) x (n-1) matrix when n parameters are being estimated.

The Test: Consider a regression equation of the form

$$y = \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p + \varepsilon,$$

where ε is normally distributed with mean 0 and standard deviation σ. A sample of N independent observations .˙. taken and the hypothesis $H_0 : \sum_1^p \beta i = c$ (some constant) is to be tested.

Solution:

$$\text{Let } y = \begin{pmatrix} y_1 \\ \cdot \\ \cdot \\ \cdot \\ y_n \end{pmatrix}, \; X = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ & & \\ x_{p1} & \cdots & x_{pn} \end{pmatrix}$$

$A = X X'$, then A is a symmetric pxp matrix. The normal equation leads to the least squares estimates of the B's, namely,

$$b = A^{-1} X y \text{ , where } b = \begin{pmatrix} b_1 \\ \cdot \\ \cdot \\ b_p \end{pmatrix} .$$

The test to be used is:

$$(1) \qquad \frac{(N-p)\ (c - \sum_1^p b_i)^2}{\sum a^{ij} \quad s^2} = F_{1\ ,\ N-p}$$

where N = number of observations in the sample

p = number of regression coefficients (excluding a) which are estimated

c = some constant (c = 1 in cases of linear hypothesis)

$\sum_1^p bi$ = sum of the regression coefficients (excluding a)

a^{ij} = elements of the A^{-1} matrix. The a^{ij} are the c_{ij} values obtained in the back solution of the Doolittle method,

and

$$s^2 = Y_i^2 - \sum(bi^2 \sum Xji^2) \ -2 \sum(\ bi \cdot bj \ \cdot \sum X_i \ X_j \ )$$

The statistic (1) has an F distribution with 1 degree of freedom in the numerator and N-p degrees of freedom in the denominator. Large values of F are critical.

APPENDIX C

A t TEST FOR TESTING THE MEANS OF THE GROSS INCOME BY USING THE POOLED VARIANCE OF THE MEANS WHEN THE REGRESSION COEFFICIENTS FOR THE EXPERIMENTAL AND CONTROL TOWNSHIP ARE INTERCHANGED

A t TEST FOR TESTING THE MEANS OF THE GROSS INCOME BY USING THE POOLED VARIANCE OF THE MEANS WHEN THE REGRESSION COEFFICIENTS FOR THE EXPERIMENTAL AND CONTROL TOWNSHIPS ARE INTERCHANGED

The simple t test of means was adapted from Snedecor's book Statistical Methods on page 77. The test was used to discover whether the estimated gross income in the experimental and control townships differed from the estimated gross income when the regression coefficients were interchanged. Consider the experimental township problem. The gross income for each farm was estimated by using the experimental township regression coefficients. The gross income for each experimental township farm was again estimated by using the control township regression coefficients. The sum of the gross incomes is 379,341 and divided by 32 degrees of freedom (n-1) = a mean gross income of $11,495.18 which is the mean of the estimated gross income when the experimental regression coefficients are used. The sum of the gross incomes for the experimental township when the control regression coefficients are used is 392,224 divided by 32 = $11,885.57 which is the mean gross income for the experimental township when the control township regression coefficients are used. The difference between the mean gross incomes is $39.39. The results are listed as follows:

Experimental Township		Number of Farms	Degrees of Freedom	Mean Gross Income	Sum of Squares
Experimental	bi's	33	32	$11,495.18	5,382,032,599
Control	bi's	33	32	$11,885.57	5,829,987,244

Sum = 64 Difference = $\bar{X}$ \$390.39 SX^2 = 11,212,019,842

Pooled variance = s^2 = 11,212,019,843/ 64 = 175,878,810.5

$s\bar{x} = 2\ s^2 / n = 2\ (175,878,810.5) / 33 = 3258.44$

$t = 390.39 / 3258.44 = .1198$

For 64 degrees of freedom $t_{(.95)} = 1.9976$

t of $.1198 < 1.9976$ so it is concluded that the regression coefficients for the control township are not significantly different from the regression coefficient for the experimental township when they are both used to estimate gross income in the experimental township.

The calculations used to estimate t in the above section are summarized in the following equation:

$$t = \bar{x} \quad \frac{n(n-1)}{S\ x^2}$$

The gross income for the control township was estimated by using the control township regression coefficients and by using the experimental township regression coefficients. The results are as follows:

Control Township	Number of Farms	Degrees of Freedom	Mean Gross Income	Sum of Squares
Control bi's	30	29	\$11,664.80	4,666,643,308
Experimental bi's	30	29	\$11,676.73	4,634,915,594
		58	Difference 11.93	Sx^2=9,301,558,902

t = .0036

For 58 degrees of freedom $t_{(.95)} = 2.0016$

t of .0036 < than 2.0016 so it is concluded that the regression coefficients for the experimental township are not significantly different from the control township regression coefficients when they are used to estimate gross income in the control township.

Date Due

MAR 19 1992			

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