ECONOMIC ANALYSIS OF RESOURCES WITH SPECIAL REFERENCE TO INTERFARM RELATIONSHIPS

A Thesis

Presented in Partial Fulfillment of the Requirements

for the

Degree of Master of Science

Major in Agricultural Economics

in the

University of Idaho Graduate School

by

Ralph Thomas Schotzko

July, 1971

This thesis of Ralph Thomas Schotzko for the Master of Science Degree with major in Agricultural Economics and titled "Economic Analysis of Resources with Special Reference to Interfarm Relationships" was reviewed in rough draft form by each Committee member as indicated by the signatures and dates given below and permission was granted to prepare the final copy incorporating suggestions of the Committee; permission was also given to schedule the final examination upon submission of two final copies to the Graduate School Office:

Major Professor Karl Lindeborg Date 7/18-71

Committee Members Dale O. Everson Date 7/13/71

Norman E. Fobes Date 7/14/71

E. L. Michalson Date 7/14/71

Reviewed by:

Department Head Norman E. Fobes Date 7/14/71

College Dean Don R. Marshall Date 7/19/71

Approval granted by a majority vote of the candidate's Committee at the final examination:

Major Professor Karl Lindeborg Date 7/19-71

Reviewed by the Graduate Council; final approval and acceptance is granted:

Graduate School Dean Edgar H. Schuster Date 8-4-71

BIOGRAPHICAL SKETCH OF THE AUTHOR

Ralph Thomas Schotzko was born in Lewiston, Idaho and spent the first years of his life in Clarkston, Washington. He attended parochial school and high school in Clarkston.

Upon graduation from high school he enrolled at Lewis-Clark Normal and completed his first two years of college at this school.

The author then transferred to the University of Idaho. After one year at this institution he entered the Peace Corps and was sent to Thailand for two years. At the end of his Peace Corps service he returned to the University of Idaho and was graduated with a Bachelor of Science degree in Agricultural Economics in 1967.

At this time the author was called for military service and spent the next two years in New Jersey.

Upon release from military service he returned to the University of Idaho for graduate work of which this thesis is the result.

ACKNOWLEDGMENTS

It is impossible to truly appreciate the amount of effort required by the preparation of a thesis. It is equally impossible to gauge, beforehand, the amount of guidance and assistance required by the author. It is also possible that hindsight, being drawn upon immediately after completion of the thesis, may not be objective enough to give credit to all who deserve it. The author, therefore, would like to thank all those faculty members at the University of Idaho who so willingly provided answers to the author's numerous questions.

There are several faculty members in the above group who because of their continued assistance deserve special mention. The members of the author's graduate committee, Dr. Dale Everson, Dr. William E. Folz and Dr. E. L. Michalson, deserve special thank you for their assistance in preparing a thesis that has clarity of thought and is statistically correct. The expression of gratitude deserved by Dr. Karl Lindeborg, the author's major professor, cannot be adequately expressed in words. His guidance and assistance was invaluable in the preparation of this thesis.

The author's wife is also deserving of special recognition. Without her perseverance and confidence in the author it is doubtful that this study would have been completed satisfactorily.

Last, but not least, the author wishes to thank his typist, Mrs. Carolyn Gravelle, whose selfless efforts helped the author to meet his personal time schedule.

TABLE OF CONTENTS

CHAPTER		PAGE
	ACKNOWLEDGMENTS	iv
	ABSTRACT.	vii
1.	INTRODUCTION	1
	A. Objectives of the Study.	10
2.	PREVIOUS WORK DONE.	12
3.	METHODOLOGY	18
	A. Introduction	18
	B. General Statistical Assumptions. . .	19
	C. The Cobb-Douglas Production Function	23
	D. The Analysis of Management	26
	E. Causal Assumptions	32
	F. Summary	37
4.	ANALYSIS OF RESULTS	39
	A. The Data	39
	B. The Production Functions	41
	C. Marginal Value Products.	45
	D. The Analysis of Management	52
5.	SUMMARY & CONCLUSION	61
	BIBLIOGRAPHY	63
	APPENDIX	65

LIST OF TABLES

TABLE		PAGE
I.	Three Production Functions with Varying Independent Variables	43
II.	Marginal Value Products Estimated from the Three Production Functions.	47
III.	Management Analysis I with Seven Independent Variables	57
IV.	Management Analysis II with Six Independent Variables	57
V.	Management and Random Standard Deviations . . .	57

ABSTRACT

The purposes of this thesis were twofold. The first of these was the estimation of production functions for agricultural income in Custer and Lemhi Counties. In this portion of the study emphasis was placed on the marginal value products for the independent variables with added emphasis on the marginal value products for the natural resources used in agriculture.

The Cobb-Douglas form of least squares regression was used in estimating the production functions.

The marginal value products indicated that four input groups earned good returns. These were current operating expenses, public range expenses, machinery maintenance and depreciation and livestock investment.

There were two inputs that appeared to be slightly over-utilized. These were land and labor.

Water was included in the function but the estimates of the regression coefficient for the variable were not significant.

Suggested adjustments for increasing income were based on the increase of livestock investment.

The elasticity of production for these functions was equal to one.

The second purpose of this study was to obtain estimates of the effects of management or interfarm relationships. These estimates were based on the residual sum of squares from the

above production functions. The residual sum of squares was partitioned into two parts using an analysis of variance approach. The result of this partitioning included an inter-farm, or management, effect and a random effect. These effects provided estimates of the variances for management and random effects.

The standard deviation obtained from the estimated variance for management indicated that, given an adjusted mean income of $17,250, 68% of the observations on total adjusted income would fall in the range, $15,350 to $19,380, if equality of inputs were assumed.

Using the standard deviation for the random effects it was determined that a rancher with an average adjusted income of $17,250 could expect 68%, or approximately seven yearly incomes out of ten, to be in the range, $14,080 to $21,120.

On the basis of the management analysis it was recommended that ranch managers in the study area could estimate their management ability by comparing their adjusted gross income, averaged over four years, with the estimate of income based on the average inputs for their ranch. If the difference between the actual and the estimated income, taken in logarithmic form, approached or exceeded the standard deviation for the effects of management, the manager can be considered above or below average depending on whether the difference is positive or negative.

Chapter 1

INTRODUCTION

Man has long been concerned with resources. Even as a hunter man's life depended on adequate natural resources. Without adequate water and feed for the wildlife the hunter's life was endangered. Then as man turned to cultivation of the soil for sustenance he began his attempt to control the natural resources around him and to put them to use in providing for a better life for man. This pattern of man's use of resources has continued down through time. Even today nature still provides those elements basic to life. Consider, for example, the source of feed, water and oxygen. These examples are either classed as resources or directly obtained from resources.

The utilization of natural resources has changed considerably down through the ages. The first cultivators utilized only enough land to provide the basic needs of the individual cultivator. The pattern of utilization has changed to the extent that national priorities now strongly influence resource utilization.

The influence of national interests on the use of resources has appeared only relatively recently. The beginnings of this attitude can be traced to the 16th century, which was the beginning of the mercantilist period in economic history.[1]

---

[1]Robert Lekachman, A History of Economic Ideas (New York: Harper and Row, 1959), p. 34.

The prevailing idea was to produce as much as possible for export.[2] Since the wealth of a nation was the amount of bullion on hand every self-esteeming country wanted a favorable balance of payments.[3] Although large-scale manufacturing appeared during the mercantilist period much of the activity revolved around products from the agricultural sector. The important deviation from the pattern in the medieval ages was the market place. In the medieval age the market place was quite local in nature and generally isolated from other markets. During the mercantilist period the market expanded beyond all boundaries, whether they were city, state or nation.

Regardless of the validity of prevailing attitudes government business was conducted according to them and resources, whether in the form of bullion or products obtained from the use of resources, were very important in all markets.

Although natural resources dominated the resource "scene" some thought was also being given to human resources. For example, David Hume said that "For men and commodities are the real strength of any community."[4] Human resources have not diminished in importance since the time of Hume.

All of the economically developed countries have been able to develop their resources in such a way so as to reach

---

[2]Ibid., p. 38.

[3]Ibid., p. 42.

[4]Ibid., p. 39, citing David Hume, Writing on Economics, ed. Eugene Rotwein (Nelson, 1955), p.45.

Their present state of development. Any number of possible combinations of human and natural resources may have been used to reach the present level of achievement; however, the fact remains that resources, per se, were a very important part of the growth process.

Resources still play an important role in both the developed and under developed areas of the world. However, the quality, distribution and amounts may vary considerably from area to area. For example, the distribution of human resources in the United States is considerably different from that of most developing areas.

It is this difference of quality, distribution and amounts of resources that forces different approaches to the problems of economic growth in different areas. Whereas in the U.S. tremendous concern has been generated in the past few years over the depletion or pollution of our natural resources, the underdeveloped nations are more concerned about utilizing their resources in such a manner so as to obtain the greatest economic return. In other words, Americans are beginning to actively analyze resources for their esthetic value as well as economic benefits. Consequently, we find that people are openly questioning the value of additional production in terms of blue sky, clear water and scenery. The White Clouds debate and the analysis presently being conducted on the Salmon River can be cited as areas of concern that involve esthetic considerations.

Idaho is particularly dependent upon natural resources. Mining, lumber and agriculture are among the most important industries. According to Peterson these three industries accounted for some $640,000,000 worth of gross output in 1963.[5]

In discussing the economic structure of Idaho, Peterson states:

> Idaho's economic base rests largely on raw materials and related processing sources of income and output. In this regard, farming, mining, and lumbering (representing raw materials) and food, wood products, and chemicals (representing raw-materials processing) combined constitute a large percentage of the gross output and value created in Idaho. In addition, net exports and multipliers are generally larger in these industry groups than for most other lines of business. In fact, the values of the multipliers are also large enough to suggest that increases in final output among these five lines have significant growth-generating potentials for Idaho.[6]

Of the three extractive industries agriculture is the most important with approximately $454 million worth of gross output in 1963.[7] Consequently, we would expect to find a much higher percentage of the population associated directly with farming in Idaho than for the entire nation. This is, indeed, the situation in Idaho with approximately 25% of the population living on farms.[8] However, the percentage is decreasing with the movement of people from the rural counties to the urban areas both in and out of the state. In fact, Peterson also

---

[5] R. D. Peterson, "Economic Structure of Idaho" (Moscow, Idaho: Bureau of Business and Economic Research), Report No. 12, July, 1970, p. 17.

[6] Ibid., p. 64.

[7] Ibid., p. 64.

[8] U.S. Department of Commerce, "Statistical Abstract of the U.S., 1970" (91st ed.; Washington, D.C.: U.S. Government Printing Office, July, 1970), p. 17.

points out that Idaho lost 4% of its residents from the 25-44 age group between 1950 and 1960.[9] This out-migration is further emphasized by the 1964 Agricultural Census population distribution data.[10] These data emphasize the fact that there is a distinct out-migration in the lower age groups, particularly from the rural counties.

Mechanization of farming and the increase in economies of size have been a major factor in the migration from rural to urban areas. Today, however, it seems plausible, to expect an interaction between additional mechanization and available labor supply. As the out-migration continues, especially among the younger members of the labor force, there may be a labor shortage in the rural areas. This could force the farmer to make even greater investments in machinery to compensate for the lack of labor. Should this be the case, and in formal interviews with a number of ranchers in Custer and Lemhi counties during the summer of 1970 give some credibility to this possibility, there will be a continued out-migration from the rural counties.

It would appear, then, that while natural resources will continue to play an important role in the economy of Idaho, the overall availability of human resources may decline as more and more people migrate to the large, diversified labor

---

[9]Peterson, op. cit., p. 1.

[10]U.S. Department of Commerce, <u>1964 U.S. Census of Agriculture</u>, Vol. I, Part 39 (Washington, D.C.: U.S. Government Printing Office, 1967), pp. 252 & 254.

markets of the metropolitan area.

Mention has already been made of the conflict over the use of natural resources. Since Idaho has a wealth of this commodity much interest has been focused on the state in recent years.

Idaho has a good supply of water and it has been the source of some concern. The arid Southwestern part of the United States is rapidly approaching the time when present sources of water will be inadequate and the states in that region have been "casting" envious glances toward Idaho and the other states which are in the Pacific Northwest. California, for example, has conceived several plans to supplement its present water supply and Idaho has not been overlooked in these plans. One such plan suggests the transportation of Snake River water from southern Idaho into the Colorado River and subsequently into California via the Colorado River.[11]

These plans have caused Idahoans to begin a thorough analysis of the supply of water and of the potential demand for water. Since southern Idaho is quite arid much of the analysis of potential demand has centered on potentially irr-gable land in that part of the state.

There is no question about the importance of the supply of resources. However, quite recently, increased attention has been given to the quality of these resources. Tremendous publicity has been given to the problems caused by air and

---

[11]University of Idaho, College of Agriculture, "Idaho Agricultural Science" (Moscow, Idaho, March 1964), p. 2.

water pollution. Since Idaho is not heavily industrialized, air pollution, although serious in some areas of the state, is the exception rather than the rule. Water pollution, however, is another matter. Besides the industrial pollution of water, there is increasing concern over the entry of chemical fertilizers into streams and rivers. This fertilizer is carried into the streams above and below the surface by water that drains off of irrigated fields.

The implications should be obvious and may be ominous. Assuming that present production methods do not change drastically each additional acre of irrigated land will add to the problem of water pollution. Restrictions could be placed on the use of fertilizer to reduce or eliminate this source of pollution. However, in the interim, the population continues to increase with a corresponding increase in the demand for greater output of foodstuffs which should result in much higher food prices. Likewise, if methods of pollution abatement were to be developed that did not affect production but cleansed the drainage, there would be an added social cost for implementation and operation. In the final analysis society will have to decide how much it is willing to pay for pollution control.

The amount society is willing to pay for resource use or nonuse, whether it be in esthetic or dollar value, will determine how our resources are used and how much will be put to use.

Disaggregating down to the local level (where the local level is meant to imply a distinct geographic area) the relevant question to be asked of resource utilization relates to the economic benefits of the present method of utilization. What are the economic returns from the resources as they are now used? In essence, the answer to this question is the basis of this thesis. Two counties, Custer and Lemhi, have been chosen for the analysis of resource use. There are a number of reasons for the selection of these two counties.

Agriculture dominates the economy of the study area and this is important because agriculture is a prime user of the available resources.

The study area makes up a good portion of the Salmon River drainage basin. Presently, the Idaho Water Resources Research Institute is evaluating the costs and benefits of leaving the Salmon River as it is; that is, in a natural free-flowing state. This relates directly to agriculture because most of the water used in the study area is applied to the land. In fact, over 98% of the land that is presently cropped is irrigated.[12]

In addition to the 164,800 acres[13] of land in Custer and Lemhi Counties that are presently irrigated, the Idaho Water Resources Board has estimated that there are approximately 389,000 acres[14] of potentially irrigable land. Although

---

[12]U.S. Department of Commerce, op. cit., pp. 225-226.

[13]Idaho Water Resource Board, Potentially Irrigable Lands in Idaho (Boise, Idaho: Idaho Water Resource Board, July, 1970), Summary Report No. 1, pp. 15 & 25.

[14]Ibid., pp. 15 & 25.

irrigating the additional land would not use all of the available water, additional storage facilities would be required to make water available for the duration of the growing season. But could the returns to water used in irrigation pay for the cost of the additional storage facilities and canals that would be needed to distribute the water? Could pollution abatement costs also be covered by the return to water? These questions will be considered later in the thesis.

Another important reason for the selection of these two counties is the fact that approximately 92% of the total land area is controlled either by the state or by the Federal government.[15] With such a large amount of public land one would suspect that, at least, part of the public land would be used for summer pasture. This is, indeed, the case. There are about 1,358,400 acres[16] available for grazing and this results in about 181,000 animal unit months of feed per year.[17] An animal unit month (AUM) is defined as the amount of forage necessary to support one cow or five sheep for one month.[18]

In addition to grazing public lands also have other uses. These uses are primarily recreational, such as hunting and fishing. To a certain extent these uses, particularly hunting,

---

[15] U.S. Department of Commerce, op. cit., pp. 220 & 222.

[16] U.S. Department of Agriculture, Soil Conservation Service, Boise, Idaho. (Unpublished data.)

[17] Taken from the Forest Service and Bureau of Land Management lists of grazing permits for 1967.

[18] Wesley Calef, Private Grazing and Public Lands (Chicago: The University of Chicago Press, 1960), p. 28.

compete with livestock grazing. However, the extent of competition between livestock and wildlife in grazing is not well known. In any case, this competition is beyond the scope of this thesis.

The study area is also known for its mineral resources. The White Clouds controversy provides an example of the feelings that can be aroused against mining. Although an investigation of the effects of mining in the study area should prove to be quite interesting, this method of resource utilization is also outside the realm of this particular analysis.

So, it can be seen that the agricultural industry in Custer and Lemhi counties makes extensive use of the natural resources in that area and as the population (both world and national) continues to grow, it is conceivable that there will be added pressure to bring more land into production and intensify the production methods now used. There may also be pressures to allocate resources to their most economically efficient uses.

A. OBJECTIVES OF THE STUDY

So far, the discussion has dealt with resources in general terms. The purpose of this thesis is to analyze, critically, resource use as it applies to agriculture in Custer and Lemhi counties. In order to do this it will be necessary to develop production functions for the entire study area. In the development of these functions it is essential that all relevant inputs be included. Therefore, a series of aggregate production functions will be developed for the agricultural industry in the study area.

These functions will be the source of the estimates of the value of natural resources and human efforts which pertain to agriculture. In discussing human activity, the analysis will not be restricted to the labor input alone, but will also attempt to isolate the effects of management.

With the evaluation of the derived estimates of the marginal value products the various implications for public policy will be noted and the potential effects of different decisions will be discussed.

Chapter 2

PREVIOUS WORK DONE

A complete review of all studies on the analysis of marginal returns to resources is quite beyond the scope of this study. Therefore, this section will consider, briefly, the Cobb-Douglas production function and then concentrate on studies that have attempted to measure the management input through the use of the Cobb-Douglas function.

The history of production functions, in general, and the Cobb-Douglas production function, in particular, can be traced through the "American Journal of Agricultural Economics". There is a more concise discussion of the history of the development of production functions in Heady and Dillon's Agricultural Production Function.[1] Therefore, any expansive statement on the history of production functions would be redundant. However, it is interesting to note, in passing, that, although much work has been done on the application of production functions to agriculture in the United States, the first such application was carried out by an economist in Japan.[2]

In perusing the literature on production studies three distinct levels become apparent. This method of analysis is based on aggregation. The first level includes those studies

---

[1]Earl O. Heady and John L. Dillon, Agricultural Production Functions (Ames, Iowa: Iowa State University Press, 1969), p. 16.

[2]Ibid., p. 26.

that deal with the physical input-output relationships. For example, determination of the optimum level of fertilization may be ascertained by applying varying amounts of fertilizer to different plots of equal size (making the assumption that all other inputs are constant and equal) and estimating output based on the yields of the various plots. Heady and Dillon provide examples of this type of study.[3]

The second level of application aggregates the inputs used in the physical production analysis over the farm-firm. Rather than considering only the fertilizer applied to a given amount of land, the total amount of fertilizer applied by the firm to its cropland becomes a relevant input. Other inputs, such as labor, crop expenses, water, etc., also are allowed to vary and become an integral part of the analysis. Bradford and Johnson[4] provide an excellent example of this type of analysis. In fact, this particular example provided a starting point for the present study. Other examples abound in the various publications pertaining to the application of Economics and of these publications, the "American Journal of Agricultural Economics" probably provides the largest number of examples.

The third level of application is on a regional or national basis. That is, the inputs are aggregated over farms. An excellent example of this type of research is the study done

---

[3]Ibid., p. 266.

[4]Lawrence A. Bradford and Glenn L. Johnson, Farm Management Analysis (New York: John Wiley & Sons Inc., 1953), pp. 145-152.

by Ruttan for Resources for the Future, a non-profit research organization.[5] The approach used in the present study is similar to this level of aggregation in that the derived production functions contained herein are based on the aggregation of data obtained from a sample of farms over a two county area.

One input that is particularly relevant to the second and third levels of application has quite often been assumed to be a constant, primarily, because of the fact that it is exceedingly hard to measure accurately. That is the management input.

Although the importance of management as a factor of production has been recognized for some time the effective analysis of this input has not moved forward as rapidly as the analysis of production functions. In considering past attempts at the measurement of management as an input, a 1946 article by Heady provides a good starting point.[6] He explicitly referred to the implicit managerial effect and made three suggestions about imputing a return to management. Two of these are worth noting in that they provide a point of reference for later studies. Heady stated that:

> The difference between the individual farm's actual return and that expected on the basis of rates earned within the industry reflects returns to management more accurately than a residual profit computed from market rates on resources employed.[7]

---

[5] Vernon W. Ruttan, The Economic Demand for Irrigated Acreage (Baltimore, Md.: The John Hopkins Press, 1965).

[6] Earl O. Heady, "Production Functions from a Random Sample of Farms", Journal of Farm Economics, 28:1003 n. 9, Nov., 1946.

[7] Ibid.

Additionally, he notes that "a percentage difference, while not attributing a specific amount to management, may be even more accurate in indicating the extent to which management is above or below average."[8]

The residual profit idea is nothing more than budget analysis. Since the only rate of return that is unknown is that accorded to labor and management. This type of approach could lead to inefficient allocation of resources through the assumption that each resource, other than labor or management, is earning a market rate of return. This may be true in some instances, but it is also possible that some or all of the resources are earning more or less than the market rate. If a particular resource is assumed to be earning more than it actually earns, the estimated returns to labor and management will be biased downward. The reverse situation is also possible.

Another problem is that since labor and management are often combined in budget analyses the return to management depends upon the wage rate the operator feels his labor is worth.

Given these weaknesses, it would seem to be almost impossible to derive an accurate estimate of the return to management through budget analyses.

Heady's two suggestions constitute a progression because he goes from absolute deviation to percentage deviation. This study will attempt to continue this progression by

---

[8]Ibid.

developing a probability distribution for these deviations.

Attempts to estimate statistically the return to management do not appear to have been particularly successful. Few studies of this type can be found in the literature. However, three such studies have been found. The first in an unpublished dissertation that entered management as an explicit variable in a production function estimation study and found that the resulting coefficient for management was insignificant at the 5% level.[9]

The second study to be considered was made by Mundlak.[10] He estimates a Cobb-Douglas production function for a group of farm-firm with management implicit in the function. To make management explicit he assumes that there are constant returns to scale. Since the sum of the regression coefficients, Σb_i, equals the elasticity of production constant returns to scale prevail when the sum equals one. Therefore, the difference, $1 - \Sigma b_i$, is the management effect. As long as the sum of the coefficients is less than one there is no problem and the coefficients obtained in this particular study met this criterion. However, he does not consider the possibility that the sum might be equal to or greater than one.

The third approach to the problem, which was presented

---

[9]Earl O. Heady, Glenn L. Johnson and Lowell S. Hardin (Eds.), Resource Productivity, Returns to Scale, and Farm Size (Ames, Iowa: The Iowa State College Press, 1956), p. 157, n. 10.

[10]Yair Mundlak, "Production Function Free of Management Bias", Journal of Farm Economics, 43:44-56, February, 1961.

by Rasmussen, used the analysis of variance to isolate the management effect.[11] He partitions the residual sum of squares from a Cobb-Douglas regression analysis into two parts: random effects and managerial effects. This approach is superior to those mentioned above for several reasons. First of all, Rasmussen used data that had been compiled over four years. This helped to reduce the random effects of such things as weather by spreading the effect over the four years. This also helped to establish the managerial ability of individual operators by measuring their ability to adjust to random influences. Secondly, whereas Heady does not indicate how the influence of random factors may be extracted from the deviation, Rasmussen explicitly suggests a method for the separation of random effects from managerial effects. Thirdly, Rasmussen's approach is not restricted to constant returns to scale as is Mundlak's, simply because Rasmussen does not directly rely upon the coefficients for the measurement of the influence of management in the sense that Rasmussen uses the error sum of squares while Mundlak uses the regression coefficients.

---

[11] Knud Rasmussen, Production Function Analyses of British and Irish Farm Accounts (Sutton Bonington, Loughborough, England: University of Nottingham School of Agriculture, June, 1962), pp. 16-25.

Chapter 3

METHODOLOGY

A. INTRODUCTION

The development of a methodology with which to analyze a problem follows certain logical steps.

Once the objectives have been established two decisions must be made. These decisions concern the selection of an appropriate estimating function and the data needed in fulfilling the objectives.

If the primary objective were to obtain an estimating equation that provided, as accurately as possible, estimates of output, then it would be necessary to produce several different estimating equations in order to determine the most accurate function. However, this process has been reversed here. It was decided that, given the objectives, the Cobb-Douglas type of function would produce adequate results, besides allowing the Rasmussen method of management analysis to be used.

Once the estimating function was chosen the data were grouped according to the statistical requirements.

This chapter will present the following information. First, there will be a discussion of the statistical requirements for any linear estimating equation. Since the Cobb-Douglas function is linear when transformed into logarithms, it is necessary to consider these general requirements. Secondly, the Cobb-Douglas function will be described. Its advantages and disadvantages will be included in the description.

Since the analysis of the effect of management is based on the residuals, its presentation follows logically from the discussion of the regression analysis.

The final portion of this chapter will be concerned with those inputs which are important to the production process. The rationale behind the selection of inputs and the grouping of inputs will be presented here.

B. GENERAL STATISTICAL ASSUMPTIONS

In econometric work several different mathematical equations exist which may be used in the estimation of linear production functions. Therefore in any given situation one or more equations may provide a suitable approximation to the actual production function. In general, these estimating equations are normally expected to conform to a set of statistical requirements or may be transformed in such a manner so as to conform to these requirements. These conformable equations are grouped together under the general name, General Linear Model.

The set of assumptions required by the General Linear Model are relevant to this study in that the method of production function estimation used in this analysis is conformable.[1] The importance of these assumptions, or requirements, will be indicated in the discussion of the individual assumptions.

First, as a point of clarification, the property of

---

[1]J. Johnston, Econometric Methods (New York: McGraw-Hill Book Co., 1963), p. 107.

linearity as implied by the general name means that the regression coefficients (b_i's) are all to the first power.

In discussing the various assumptions the equation $Y = XB + E$ will be used as an aid to the maintenance of clarity of thought. The dependent variable, Y, is a vector consisting of all the observed values of total output. It consists of n rows and 1 column. X represents a matrix which is composed of all of the observations on the independent variables. This matrix has n rows and p columns where n is the number of observations on X; and p is the number of independent variables. For expository purposes, the constant term will be disregarded. B is also a vector composed of the regression coefficients with p rows. E is the error term and it is also a vector being composed of n rows. The error term is equal to the difference between the observed value of Y and the estimated value of Y. This error term plays a particularly important role in the statistical assumptions.

The B vector in this general approach is estimated in such a manner so as to minimize the sum of the error terms squared. This squaring is necessary because the estimation is carried out in such a manner that the sum of the differences between the observed and estimated values of Y equals zero. Logically, this method of estimating the coefficients is called least squares regression.

There are two assumptions that pertain to the matrix of independent variables. It is usually assumed that X is a matrix of fixed numbers. This is a useful simplifying assumption that allows for the easy calculation of the coefficients and the variance of the coefficients. However, this seems to be a rather strict assumption. Consequently, it will be relaxed to the extent that X will be assumed to be a set of random numbers that is uncorrelated with the error term. This relaxed assumption is more realistic and does not create any bias in the estimated coefficients as long as the independent variables are not correlated with the error term.

The second assumption about the matrix of independent variables is concerned with the rank of the matrix. The rank of a matrix is defined as the maximum number of linearly independent columns.[2] The rank of X must be both equal to the number of independent variables and less than the number of observations. If the rank of X is less than the number of independent variables then multicollinearity exists. That is, at least, some of the independent variables are related and this will cause a bias in the estimates of the regression coefficients. If the number of observations is less than the number of independent variables it is not possible to obtain estimates of the regression coefficients. If the number of observations equals the number of independent variables estimates of the regression coefficients can be obtained but the variance of the estimates would be undefined and no confidence could be placed in the estimates.

There are three other assumptions pertinent to the

---

[2] Ibid., p. 91.

General Linear Model. These assumptions concern the vector of error terms. The first of these assumptions is that the expected value of the error term is zero. That is equivalent to saying that the mean of the errors is zero. As noted above, least squares regression estimates the function in such a manner that the sum of the residuals is equal to zero. Therefore, the mean of the error terms must be zero. This assumption is essential in proving that the estimates of the regression coefficients are unbiased.

The next assumption states that the expected value of the vector of error terms multiplied by its transpose is equal to the variance times the identity matrix. This is used in the proof that var $(\hat{\beta}) = \sigma^2(X'X)^{-1}$. Implicit in this assumption is the idea that the errors are independently distributed. This independent distribution is particularly important when using least squares estimates of the regression coefficients. Johnston has listed the consequences of the lack of compliance with this assumption.[3] The estimates of the coefficients will be unbiased, but the sampling variances will be much larger than necessary if the error terms are not independently distributed. In fact, estimates obtained by the usual least squares estimation are invalid in that the formulas used in the estimation procedure are invalid. The formulas usually applied in the t-test or F-test are also invalid.

Lastly, it is assumed that the error terms are distributed

---

[3] Ibid., p. 179.

normally. This assumption allows for the construction of hypothesis tests. Both the t-test and the F-test require normal distribution for a valid comparison.

These are the assumptions that must be met in order for this analysis to be of any consequence. However, these are assumptions that apply to all estimation methods of the General Linear Model form and do not include those assumptions peculiar to a given type of estimating function. Consequently, it is necessary to consider the assumptions which are characteristic of the Cobb-Douglas type of estimation and also those necessary for the analysis of the effect of management. The discussion of these particular assumptions will be considered in conjunction with the description of the methods to be used.

C. THE COBB-DOUGLAS PRODUCTION FUNCTION

> Of the possible algebraic forms, Cobb-Douglas functions have been the most popular in farm-firm analysis. This algebraic model provides a compromise between (a) adequate fit of the data; (b) computational feasibility and (c) sufficient degrees of freedom unused to allow for statistical testing. However, it probably has greatest use in diagnostic analyses, reflecting marginal resource productivities at mean levels of inputs.[4]

This quotation states, quite aptly, the reason for the popularity of the Cobb-Douglas function and why it was selected for use in this study. Its diagnostic potential was most important in the selection because it was precisely these marginal resource productivities that were of primary concern.

---

[4] John L. Dillon and Earl O. Heady, Agricultural Production Functions (Ames, Iowa: Iowa State University Press, 1961), p. 228.

However, there is an additional reason behind the use of this type of estimating equation. The study of the effects of management as presented by Rasmussen used the Cobb-Douglas function in estimating the regression coefficients. This increased the desirability of the function.

The general form of the Cobb-Douglas function is $Y = aX^b$. As stated, this function does not conform to the General Linear Model; however, by using logarithms the function becomes conformable. The logarithmic form of the equation is $\log Y = \log a + b \log X$. The estimating equation can be expanded to include as many independent variables as desired.

The regression coefficients are obtained by applying the least squares method to the function in its logarithmic form.

The estimates of the marginal value products of the various inputs are easily calculated from this estimating equation. The marginal value product is strictly defined as the price of the product multiplied by the additional output of that product obtained by increasing one input by one unit while holding all other inputs constant.[5] The marginal value product of a given input is determined by multiplying the regression coefficient for that variable by the mean value of the dependent variable and dividing that product by the mean value of the input, or $MVP_{x_i} = \frac{b_i \bar{Y}}{\bar{x}_i}$.[6]

---

[5] Lawrence A. Bradford and Glenn L. Johnson, <u>Farm Management Analysis</u> (New York: John Wiley & Sons Inc., 1953), pp. 115-120.

[6] Ibid., p. 149.

There are several assumptions implicit in the Cobb-Douglas function. The first assumption is that "the elasticity of production is constant over all ranges of input, while the marginal product ratio changes. Constant elasticity is attained if each percentage increase in input adds the same percentage amount to output."[7] An elasticity of production greater than, equal to or less than one will bring about a percentage change in output that is greater than, equal to or less than one, respectively.

This assumption is the source of one of the advantages of the Cobb-Douglas production function. This advantage is the ease with which the elasticity of production is calculated. The elasticity in this case is computed merely by summing the regression coefficients. Obviously, since there is only one set of coefficients estimated for a function, the elasticity of production will remain constant over the entire range of data which was used in estimating the regression coefficients. This is considered a defect by some economists. However, within the range of the observations it does not seem to be particularly unrealistic. Also, since the emphasis of the analysis is placed on the mean values, particularly in computing marginal value products, the elasticity of production, as produced by the Cobb-Douglas function, should be as valid as

---

[7]Earl O. Heady, "Technical Considerations in Estimating Production Functions", Resource Productivity, Returns to Scale and Farm Size, eds. Earl O. Heady, Glenn L. Johnson and Lowell S. Hardin (Ames, Iowa: The Iowa State College Press, 1956), p. 9.

any other.

Another assumption implicit in this approach is that the complete lack of one input or input group implies an output of zero. This is an obvious defect in that the lack of public range for summer pasture, for example, while reducing the total output of most ranchers in the study area does not lead to a complete loss of output. Consequently, the strictness of this assumption is not warranted in an economic sense. However, the range of output for all inputs considered together is such that an extrapolation to the origin is considered irrelevant to this study.

The Cobb-Douglas function does not allow for decreasing total output. As inputs continue to increase in amounts used total output continues to increase. This, too, is an obvious defect and common criticism. For example, water can be applied in such large amounts so as to kill almost any crop; however, the application of that much water cannot be considered a rational action. In general, the basic refutation of this criticism is that such extremes are outside of the range of concern.

The Cobb-Douglas method of estimating production functions has its defects. However, given the range of data and the advantages noted above, its desirable qualities are sufficient in justifying its use.

D. THE ANALYSIS OF MANAGEMENT

In the Cobb-Douglas analysis the emphasis is on estimating an equation that explains as much as possible of the total variation in output or total sum of squares. However, this portion of the study will shift the emphasis from explaining the variation to a more detailed analysis of that portion of the variation that cannot be explained.

It is realistic to assume that management has an effect on total output. Given this assumption, it would also seem reasonable to assume that since management does have an effect on total output but is not included among the explanatory variables the influence of management is included in the unexplained portion of the variation. Therefore, the unexplained variation will be analyzed and broken down into two parts, the effect of management and random effects.

In the present analysis it is necessary to assume that the production planes are all parallel. That is, the production functions that could be developed from the data for each of the four years parallel each other and differ only in the constant terms. This is necessary to allow the use of the pooled within years regression coefficients in the separation of the random from the management effects.

The within years regression coefficients are estimated from the pooled data for all four years. They are used because they provide a relatively good estimate of the actual production function. This is related to the above assumption in that the yearly regressions are random deviations around the function derived from the within years regression.

The reason for using four years of data is based on the idea that random variations which occur in one year will be averaged over the entire period and will thereby be reduced in total influence. Also, the use of four years of data will allow the managerial effect to be estimated more precisely. Using data from one year does not allow the estimation of management because, for example, a poor manager might receive a good return that particular year that is due strictly to random effects while the good manager has a lower than usual income. The concentration on this one year will not reflect the ability of good management to minimize or the inability of poor management to maximize returns. In other words, the efficiency in allocating resources by management is poorly measured by a sample taken from only one year.

The breakdown of the error sum of squares and the estimation of the two separate effects is handled in the following manner (see appendix Table II).[8]

Y_{ij} = log adjusted total income where i = year and j = farm.

$Y_{.j} = 1/4 \sum_i Y_{ij}$; this is the 4 year average for farm j.

$Y_{i.} = 1/18 \sum_j Y_{ij}$; average income for year i.

$Y_{..} = 1/72 \sum_i \sum_j Y_{ij}$; general mean.

$X_{n_{ij}}$ = log n^{th} input for year i and farm j.

---

[8]Knud Rasmussen, Production Function Analyses of British and Irish Farm Accounts (Sutton Bonington, Loughborough, England: University of Nottingham School of Agriculture, 1962), pp. 18-20.

$X_{n_{.j}} = 1/4 \sum_i X_{n_{ij}}$; average of input n for farm j.

$X_{n_{i.}} = 1/18 \sum_j X_{n_{ij}}$; average amount of input n in year i.

$X_{n_{..}} = 1/72 \sum_i \sum_j X_{n_{ij}}$; general mean for input n

where $i = 1, 2, 3, 4$

$j = 1, 2, 3, \ldots, 18$

$n = 1, 2, 3, \ldots, p$

$b_n = (n = 1, 2, 3, \ldots, p)$ where b is the regression coefficient for the n^{th} input.

The error sum of squares is calculated by the following expression:

$$\text{I.} \quad \sum_i \sum_j ((Y_{ij} - Y_{i.}) - b_1 (X_{1_{ij}} - X_{1_{i.}}) - \ldots - b_n(X_{n_{ij}} - X_{n_{i.}}))^2 .$$

The yearly means, $Y_{i.}$ and $X_{n_{i.}}$, are used rather than the general means, $Y_{..}$ and $X_{n_{..}}$, because this method, which is similar to the analysis of variance, assumes the squared deviations around the yearly means to comprise the error sum of squares.

As noted above, the unexplained variation is broken down into two parts, the management effect and the random effect. A reasonable estimate of the management effect is the difference between the farm average, $Y_{.j}$, and the general mean, $Y_{..}$. The random effect is, then, the error sum of squares minus the management effect. All of this may be described in mathematical terms as follows:

$$\sum_i \sum_j (Y_{ij} - Y_{i.})^2 = \sum_j (Y_{.j} - Y_{..})^2 + \sum_i \sum_j ((Y_{ij} - Y_{i.}) - (Y_{.j} - Y_{..}))^2$$

and $$\sum_i \sum_j (X_{n_{ij}} - X_{n_{i.}})^2 = \sum_j (X_{n_{.j}} - X_{n_{..}})^2 + \sum_i \sum_j ((X_{n_{ij}} - X_{n_{i.}}) - (X_{n_{.j}} - X_{n_{..}}))^2 .$$

The left hand term is the variation of each observation from the yearly average. The first term on the right hand side of the equality sign is the effect of management and the second term is the random effect. The random effect will be rearranged and, henceforth, written as $\sum_i \sum_j (Y_{ij} - Y_{i.} - Y_{.j} + Y_{..})^2$.

The management effect is estimated by the following expression:

$$\text{II.} \quad 4\left[\sum_j ((Y_{.j} - Y_{..}) - b_1 (X_{1_{ij}} - X_{1_{..}}) - \ldots - b_n (X_{n_{.j}} - X_{n_{..}}))^2\right] .$$

This expression is multiplied by 4 because it uses the farm averages. In other words, assuming the effect of management to be constant over the 4 year period it is necessary to multiply by 4 to obtain the total effect of management.

The following expression provides an estimate of the random effects:

$$\text{III.} \quad \sum_i \sum_j ((Y_{ij} - Y_{i.} - Y_{.j} + Y_{..}) - b_1 (X_{1_{ij}} - X_{1_{i.}} - X_{1_{.j}} + X_{1_{..}}) - \ldots - b_n (X_{n_{ij}} - X_{n_{i.}} - X_{n_{.j}} + X_{n_{..}}))^2 .$$

The entire analysis is based on an analysis of covariance of the randomized block form that is adjusted for that portion of the variation explained by regression. In other words, using expression III as an example, the expression, $(Y_{ij} - Y_{i} - Y_{.j} + Y_{..})$, when squared and summed over i and j is the estimate of the error sum of squares as provided by analysis of variance.[9] The independent variables are introduced into the expression to eliminate that part of the analysis of covariance error sum of squares that can be explained by regression analysis. The resulting error term has, then, been adjusted for the effects of management, yearly influences such as prices and weather and the effects of the inputs.

This is not, however, a conventional analysis of covariance in the strict sense of the term because the regression coefficients used in this analysis are the within years regression coefficients while the regression coefficients normally used in analysis of covariance are based on the relationship between the error term for Y and the error term for the independent variable.[10]

According to Rasmussen, expression II is the Between Farms variation, the variance of which is an estimate of $(4\ S_2^2 + S_1^2)$.[11] The random term, expression III, provides an estimate of S_1^2. S_2^2 is obtained by subtracting the estimate S_1^2 from the variance for II and dividing by 4.

---

[9] Henry Scheffe, The Analysis of Variance (New York: John Wiley & Sons, Inc., 1959), p. 210.

[10] William G. Cochran and George W. Snedecor, Statistical Methods (Ames, Iowa: The Iowa State University Press, 1967), p. 422.

[11] Rasmussen, op. cit., p. 20.

From these variances standard deviations can be calculated to establish boundaries around the mean and between which 68% of the population of total incomes can be expected to be found. In other words, 68% of the population can be expected to lie in the range estimated by the mean plus or minus one standard deviation. If constant levels of inputs are assumed in the population in dollar terms, which allows for internal arrangements by managers, then observations outside the boundaries would be caused by exceptional management in both the negative and positive sense.

E. CAUSAL ASSUMPTIONS

Regardless of the estimating equation used in deriving the production functions certain assumptions must be made as to what inputs are relevant in producing the output. The selection of inputs is a rather subjective process because it is impossible to include all inputs in the analysis. One reason for this is that some inputs are not measurable. For example, all attempts to include management as an explicit factor of production have yielded very poor results. Another important consideration is that as the number of variables increases the computations become quite unwieldy. Also of importance are the statistical requirements. With a large number of variables being included in the derivation of a production function the confidence limits for the estimated coefficients would be quite wide and thereby reduce the effective value of the estimates. Therefore, it is necessary to achieve a proper balance between the inclusion of the relevant variables and the statistical requirements.

The data used in this study were collected in the summer of 1970 and supplemented with data collected by Dr. Roland Bevan. Dr. Bevan's data covered the years 1960-1963.[12] There were 101 observations from which to develop the production functions. For the analysis of the effect of management there were eighteen cooperators who provided information for all four years which meant a total of 72 observations for the management study.

All of the data were provided by ranchers in Custer and Lemhi Counties.

The use of the Cobb-Douglas production function necessitates a certain amount of aggregation. The guidelines for this aggregation are provided in Bradford and Johnson.[13]

The level of output is measured in dollars. That is, total output is considered to be total income adjusted for the amount of products grown and consumed on the farm and for off-farm income. Also deleted from total income were the fixed costs, including insurance, telephone, building depreciation and maintenance and pasture rent.

Originally, there were eight different inputs or groups

---

[12] Roland Bevan, "Costs and Returns to Mountain-type Cattle Ranches in Central Idaho in 1963", Report No. 106, (Moscow, Idaho: University of Idaho Agricultural Experiment Station, July, 1965). Also see reports: no. 73, 1961; no. 82, 1962; no. 85, 1964.

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

of inputs that were considered sufficiently important to be included in the analysis. Not every input was included in all of the derived functions. As will be seen later, this was based on statistical considerations. These considerations led to the combination of inputs into groups or to deletion of inputs from the analysis. However, each of the initial input groups will be discussed here.

The size of the ranch in total acres was considered an important input and was, therefore, included in the function. No attempt was made to differentiate the various types of land. Differentiation of irrigated from non-irrigated land may have led to significantly different results; however, there was good reason to suspect such a high correlation between the water input and irrigated land that the coefficients and related marginal value products to be quite unreliable. The use of money as a measurement of size of ranch was considered, but it, too, was rejected because it was suspected that the public range permits created an upward bias in the value of the land which would lead to an under-estimation of the marginal value product for land.

Labor is another factor of production that is particularly relevant. This figure included both the amount of labor provided by the rancher and his family and hired help. It was measured in months. Although it was recognized that there are differences in the quality of labor, it was necessary to assume a constant quality of labor because of the difficulty encountered in attempting to measure the differences.

The present value of machinery and equipment was another input included in the original function. Realizing that this input is a stock rather than a flow resource it was not expected to provide an adequate measure of its role in the productive process; however, due to the fact that this is one of the major forms of investment it was included. This variable was measured in monetary terms.

The next input was the inventory value of the livestock. The beginning inventory measured in dollars was the variable used. Although there were isolated observations on ranches that had feeder operations as an integral part of the economic activities it was assumed that all operations were cow-calf. Here, again, the problem of a stock variable is encountered. While recognizing that this problem existed it was noted that other studies tended to use this stock variable. A notable example of this is to be found in Bradford and Johnson.[14] The marginal value product should then represent interest and depreciation of the total investment in livestock.

Since the vast majority of cropland in the study area was irrigated, water was considered an important variable. This input was measured in acre-feet. The amount of water used was determined on the basis of consumptive irrigation requirements. Consumptive irrigation requirement is defined as "the amount of water required for consumptive use that is

---

[14] Ibid., p. 146.

artificially applied to the soil."[15] This method of estimation was used because no data were available on the amount of water actually applied to the crops. The figures used were obtained by multiplying the mean seasonal requirements for a particular crop by the number of acres of that crop on a ranch and then summing over all crops on that ranch.

Current cash operating expenses were also considered relevant to the production process and therefore were included. These were broken down into three separate groups originally, cattle, crop and miscellaneous. The cattle expenses included veterinary fees, medicine, purchased feed, registration fees and other miscellaneous expenses that pertained directly and completely to the livestock enterprise. The crop expenses included such items as baling twine, seed, fertilizer, fuel and oil. However, after due consideration, it was decided that since crop expenses pertained, in most cases, to intermediate products which were used in livestock production they could be combined with current cattle expenses. The miscellaneous expenses variable was composed of maintenance and depreciation on machinery, miscellaneous expenses not easily apportioned to any particular activity and allowable car expense. The car expense was based on tax allowances. This last variable created somewhat of a problem since equipment depreciation was included twice. However, the insiginificance of the

---

[15] G. L. Corey and R. J. Sutter, Consumptive Irrigation Requirements for Crops in Idaho (Moscow, Idaho: University of Idaho College of Agriculture, July, 1970), Bulletin no. 516, p. 1.

investment in equipment variable in explaining the variation in income led to the elimination of the equipment investment variable and consequent alleviation of the problem.

The last variable to be included was the cost of grazing on public lands. This cost could have been combined directly with the current cattle expenses; however, it was hoped that the separation of this cost from the other cattle expenses would result in a reasonable estimate of the marginal value product of public range. The interest in public range is based on the fact that it is a natural resource or, more accurately, a combination of natural resources.

In total, there were eight input categories considered to be important in the total production process. The variables used throughout this study are as follows:

Y - Adjusted total income

X_1 - Total acreage

X_2 - Labor

X_3 - Machinery investment

X_4 - Livestock investment

X_5 - Water

X_6 - Current cattle and crop expenses

X_7 - Range expenses

X_8 - Machinery maintenance and depreciation.

F. SUMMARY

The analysis used allows the use of a concise, straightforward presentation.

The first step involved testing the data to ensure that the basic assumptions on which the regression was based were met. This was necessary for the analysis of the regression to be valid. Secondly, the regression equations were derived. From these equations estimates of the marginal value products were obtained and, although not explicitly mentioned above, confidence limits were established. Thirdly, the residual sum of squares, as left unexplained by the within years regression coefficients, was partitioned into two segments, random and management. The variances from these two segments allowed the formation of confidence limits which provided boundaries into which 68% of the population of observations in the study area could be expected to fall as a result of the effect of management.

Having reached this point the results can be analyzed and interpreted. This is the task of the next chapter.

Chapter 4

ANALYSIS OF RESULTS

A. THE DATA

In analyzing the results of the regression analysis and the estimates of the effect of management, it is necessary, first, to consider the data in terms of the assumptions which are required for a meaningful production function.

The first assumption required that there be no correlation between the independent variables in the regression. This was easily, albeit crudely, checked. The computer program used in estimating the regression equations contained graphs with plots of the residuals against each of the independent variables. No deviant pattern appeared in the graphs to indicate that there was any reason to suspect any correlation between the independent variables and the regression residuals. This lack of patterns also eliminated the possibility of heteroscedasticity. In other words, the assumption of a constant variance appeared to be valid.

The assumption about the rank of the X matrix is worth mentioning more for the requirement that the rank be equal to the number of regression coefficients than for the requirement that the rank be less than the number of observations. The number of observations, 101, is sufficiently greater than the number of regression coefficients, 8. However, if the rank is less than the number of regression coefficients, multicollinearity reduces the validity of any analysis based on these coefficients. The lack of an effective method of measuring the extent of multicollinearity creates a problem in eliminating it. One suggested method compares the multiple correlation coefficient with the simple correlation coefficient between two independent variables.[1] However, with no lower limits established for the ratio, this comparison becomes quite subjective.

The presence of multicollinearity causes the variances for the regression coefficients of the related variables to increase.[2] Consequently, the ratio of the regression coefficient to its standard deviation provides, at least, a partial check for multicollinearity. These t-tests will be considered with the analysis of production function equation.

Another partial check for multicollinearity is the scrutinizing of the simple correlation coefficients. A table of simple correlation coefficients is located in the appendix (Table 1).

Arbitrarily selecting a maximum acceptable level of intercorrelation equal to .6, there were five variables which had correlation coefficients exceeding this level with four other variables. Land and livestock investment were both highly correlated with four other variables. Labor, machinery investment and machinery maintenance were also highly correlated

---

[1] Lawrence R. Klein, An Introduction to Econometrics (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962), p. 101.

[2] J. Johnston, Econometric Methods (New York: McGraw-Hill Book Co., 1963), p. 204.

with four other variables. The only logical way of eliminating this pattern was to delete as many of these variables as possible. This became a major criterion in the attempt to develop a production function that provided an adequate explanation of the variation in income and yet was relatively free of statistical flaws.

Another possible problem is serial correlation among the error terms. Determination of the Durbin-Watson statistic produced a value in the zone of indeterminacy. However, the method of calculation may not have been correct because the data are composed of both cross-sectional and time-series observations. To adjust for the problem created by the combination of cross-sectional with time-series data it was necessary to eliminate twenty-nine observations. In other words, the Durbin-Watson statistic was recomputed using only those observations which had come from ranchers who had cooperated for the entire period. The results of this test were within the range of values which indicated no correlation.

Therefore, it was concluded that the data were reasonably well-suited for the regression and management analyses.

B. THE PRODUCTION FUNCTIONS

In obtaining a production function that was relatively free of the statistical problems mentioned above it was necessary to start with an estimated function that contained all of the independent variables that were hypothesized to have been important to the production process. Once this function was estimated it was possible to begin the elimination of variables that were either insignificant or created problems with intercorrelation. Table I contains the results of this portion of the analysis.

In the first derived function machinery investment was included as an explicit variable. However, it proved to be quite insignificant in explaining the variation in income. Therefore, it was not given any further consideration.

The elimination of this variable removed the problem of double-counting which was mentioned earlier.

Of the variables included in the first function, only three, machinery maintenance, livestock investment and current operating expenses were significant at the .05 level as determined by the t-test. However, water proved to be significant at the .10 level.

Besides machinery investment there are no regression coefficients listed for land or range under Function I in Table I. Although these variables were explicitly included neither land nor range had a significant effect on the coefficient of determination and the regression coefficients for both of these variables were not significantly different from zero. The t-test indicated that both were insignificant even at the .5 level. Add to this the fact that the standard error of the estimate for the equation reached a minimum before these two variables were entered into the regression analysis using the step-wise regression approach. Therefore, it was decided to use the function as presented in Table I.

TABLE I

Three Production Functions
with Varying Independent Variables

INPUT		FUNCTION		
		I	II	III
Land	X_1		.12027 (.04864)**	.10942 (.04700)**
Labor	X_2	.11551 (.1048)*	.29053 (.11101)**	.30146 (.11018)**
Machinery Investment	X_3			
Livestock Investment	X_4	.51600 (.08203)**		
Water	X_5	.03262 (.01890)	.01855 (.02107)	
Current Operating Expenses	X_6	.18244 (.04194)**	.26742 (.04528)**	.27452 (.04247)**
Range	X_7		.03350 (.01213)**	.03159 (.01192)**
Machinery Maintenance	X_8	.16100 (.08051)**	.26677 (.08902)**	.28930 (.08516)**
Constant	a	.41364	1.55591	1.52764
R^2		.8516	.8167	.8152
Sum of Regression Coefficients		1.00757 (.1051)	.99704 (.1174)	1.00629 (.1172)
t-value		.072	.025	.053

*Standard error
**Significant at .05 level

Written in equation form the first function is expressed thusly:

$$\hat{Y} = aX_2^{.11551} X_4^{.51600} X_5^{.03262} X_6^{.18244} X_8^{.16100} .$$

Although the sum of the regression coefficients was greater than one, it was not significantly different from one. Therefore, this function was assumed to have a constant return to scale.

Although livestock investment was the strongest variable in the first function it was removed from the second regression, along with machinery investment. The elimination of machinery investment was reasonable because this variable was so insignificant, as noted above, that its deletion was obvious. However, the deletion of livestock investment was not quite so obvious. The primary reason was that this input was highly correlated with four other variables. The basic concern was to obtain estimates of the regression coefficients that were as accurate as possible. It was felt, then, that the elimination of livestock investment would allow the other coefficients to estimate, more accurately, the population regression coefficients.

As can be seen in the correlation matrix in appendix Table I, land was also highly correlated with four other inputs. However, the accent of this study was on natural resources and for that reason land was left in the regression.

Function II in equation form is as follows:

$$\hat{Y} = aX_1^{.12027} X_2^{.29033} X_5^{.01885} X_6^{.26742} X_7^{.03350} X_8^{.26677} .$$

Function III follows logically from Function II. The water variable's regression coefficient in Function II was insignificant and this variable also caused an increase in the standard error of the regression equation by an amount equal to the difference of the errors listed under the sum of the regression coefficients for Functions II and III.

As can be noted in Table I, the elasticity of production for both Function II and Function III are insignificantly different from one. Consequently, all three functions have unit elasticities of production.

The mean adjusted income, as provided by all three functions, was approximately $17,970. This figure is the geometric mean of the observations which provided the basis for the analysis. It cannot be multiplied by the number of the ranches in the study area to obtain an indication of total agricultural income. The only method by which total adjusted income might be determined would be to take the aggregates of the independent variables over the entire study area and use these figures in estimating the income for the two counties from agriculture. However, an estimate of this type would probably be quite inaccurate due to that fact that the confidence bounds for income estimates increase as they increasingly differ from the mean value.

C. MARGINAL VALUE PRODUCTS

Probably the most important results that can be obtained from this type of regression analysis are the returns to scale and the marginal value products. The returns to scale were mentioned earlier. The elasticity of production indicated that the functions provided constant returns to scale.

The marginal value products are of particular interest for two reasons. They provide a rationale for general statements concerning the readjustment of the levels of inputs to achieve a greater income. The marginal value products also provide an estimate of the returns to the natural resources used in the production process. The relevance of this lies in the desire for the efficient allocation of resources.

Unfortunately, with composite groupings within some of the variables it is not possible to be specific about the adjustments necessary for obtaining a greater income. However, this does not imply that any general statements will be invalid.

Table II contains the estimates of the marginal value products. The marginal value products were calculated by multiplying the regression coefficient for the i^{th} input by the mean adjusted income and dividing this product by the mean value of the i^{th} input or, algebraically, $MVP_{x_i} = \frac{b_i \bar{Y}}{\bar{x}_i}$.

In discussing the marginal value products emphasis was placed on those figures which had the lowest standard deviation relative to the regression coefficient. In other words, when more than one estimate of a regression coefficient was derived the most significant coefficient was analyzed.

The marginal value product for land indicates that the use of an additional acre would yield a return of $3.41. This marginal value product, at first, appeared to be rather low. However, on the basis of the 1964 agricultural census, which

TABLE II

Marginal Value Products
Estimated from the Three Production Functions

Input	Function		
	I	II	III
Land		$ 3.41 (1.37)	$ 3.11 (1.33)
Labor	$94.61 (85.90)*	$237.96 (90.92)	$246.91 (90.24)
Water	$ .56 (.33)	$ .32 (.36)	
Current Operating Expenses	$ 1.54 (.36)	$ 2.26 (.36)	$ 2.32 (.36)
Range Costs		$ 3.64 (1.32)	$ 3.43 (.79)
Machinery Maintenance	$ .77 (.38)	$ 1.28 (.43)	$ 1.39 (.41)
Livestock Investment	$ .20 (.03)		

*The distance of the mean value to the upper and lower boundaries which should include 68% of the observations.

indicated that the value of land and buildings per acre was $110 and $105 for Custer and Lemhi Counties respectively, this value did not seem unduly low.[5] If this value was assumed to represent a 3.5% return on investment in land, the average value of land would be approximately $97 per acre. The difference, if attributed only to buildings, may be slightly high. However, range permits tend to bias upwards the value of land and, therefore, the return, as determined here, on the investment of land should be within reason.

The marginal return to labor appeared to be slightly low. If it is assumed that the operator's labor was worth $4000 per year, the average cost of labor per month was approximately $330. Using a value of $3600 for operator's labor the monthly average cost was $311. It is obvious that the marginal value product of labor, $247, is less than the average monthly cost for either assumed value of operator's labor. However, neither average monthly cost differed from the marginal value product by the value of one standard deviation. Consequently, the amount of labor employed, on the average, may not provide a dollar for dollar trade-off between input and output, but a radical readjustment in the employment of labor is certainly not necessary.

The effect of intercorrelation can be noted by the difference in the values of the marginal value product for

---

[5] U.S. Department of Commerce, 1964 United States Census of Agriculture (Wash., D.C.: Government Printing Office, 1967), Vol. I, Pt. 39, pp. 220-222.

labor between Functions I and II. Labor was highly correlated with livestock investment and this latter input was so powerful that it affected, considerably, the estimate of the marginal value product for labor.

The regression coefficient and the resulting marginal value product for water present somewhat of a problem. The marginal return per acre-foot of water at the mean for Function II was quite insignificant. However, the estimated marginal value product from Equation I was significant at the .10 level. If reliance can be placed on the estimate from Function I, then an acre-foot of water is yielding a return seven times greater than the cost of the water. Assuming that the water applied meets the consumptive irrigation requirements, the cost of the water to the rancher was about $.08 per acre-foot.

There are three ways in which this marginal value product may be of consequence. First, it has been recently estimated that there are approximately 389,000 acres of potentially irrigable land of Class I, II or III quality in Custer and Lemhi Counties.[4] As the Idaho Water Resource Board proceeds in its estimation of water needs in Idaho it will need estimates of this type in evaluating potential irrigation projects in the study area. Secondly, there has been some discussion about inter-basin water transfers within the state. The comparison of marginal value products between basins for

---

[4] Idaho Water Resource Board, Potentially Irrigable Lands in Idaho (Boise, Idaho: Idaho Water Resource Board, July, 1970), Summary Report No. 1, pp. 15 & 25.

water would provide a guideline in determining the maximum cost of transporting water economically. Recreational benefits from the water, if they can be measured, provide another possible comparison in attempting to achieve efficient allocation of resources.

Current operating expenses were shown to have a quite reasonable marginal return. However, since this variable is actually an aggregate of a number of inputs, it is impossible to make any definite statements. It would certainly indicate that, in general, increases in the inputs in this variable would be warranted. There are several obvious inputs that could use a more detailed analysis such as fertilizers, veterinary and medicinal expenses for the livestock and feed supplements.

The marginal value product for public range was the greatest per unit of input of any of the input variables. It indicated a 343% return on an additional dollar of input at the mean level of the input. With an average cost of an animal-unit-month of grazing of about $.50, the marginal return per unit-month was approximately $1.71. This may appear to be too high, but it can be, at least, partially justified. First, for those ranchers who have had to buy their ranches since the institution of the Taylor Grazing Act, the cost of the ranch has included an implicit amount for the federal grazing permit. Therefore, this return per animal-unit-month must also cover the return on the investment in range permits that was implicitly included in the market value of the ranch. Secondly, any return above and beyond the returns from the implicit investment may be considered a subsidy. With the production of a number of commodities now being subsidized, it does not seem unreasonable to subsidize the production of cattle.

Machinery maintenance with a marginal value product of $1.39 at the mean level of input also provides a reasonable return on an additional dollar of input. It does not appear to substantiate the opinion that the ranchers are overinvested in machinery and equipment. On the other hand, this marginal value product does not indicate an underinvestment in equipment either. The reason for the high return may very well be that the equipment and machinery are not depreciated out to the most economical point.[5]

Since livestock investment is measured by the total amount of money invested in cattle the marginal value product measured the return on the investment. Therefore, the marginal value product for this variable reflects a 20% return on an additional dollar of investment. A marginal return of this magnitude in a nonagricultural investment would certainly be respectable and there should be no reason for the ranchers to be denied this type of return.

In terms of adjustments to increase income, in strictly economic terms, there are several general statements which can be made on the basis of the above analysis. The marginal value product of land implies that increasing the size of the

---

[5] O. H. Brownlee and Gerhard Tintner, "Production Functions Derived from Farm Records", Journal of Farm Economics, Vol. XXVI, Aug., 1944, No.3, pp. 566-571.

ranches above the average would lead to a less than reasonable return. The implications for labor might indicate a slight reduction in the amount used; however, with a reasonable increase in livestock investment as indicated by the marginal value product, a more efficient use of labor might be more suitable. This same increase in livestock investment will obviously lead to an increase in current operating expenses through the increase in that part of expenses which pertains directly to livestock. However, an increase in crop expenses, through the use of more and better fertilizer, for example, is also a possibility. This leads to increased maintenance which is reasonable when considering the marginal value product. The only problem is public range with its institutional quality. The average rancher does not have any control over the range permits. The only possible short-run approach to bringing this marginal value product in line with the other inputs might be through increased services on the range as provided by the local grazing association. As far as water is concerned it is hard to speculate. Assuming that adequate water is already being applied to the crops and that the marginal value product is not completely unreasonable, it may not be profitable to irrigate new land when all of the costs are considered.

D. THE ANALYSIS OF MANAGEMENT

Up to this point emphasis has been placed on the explained part of the variation in the adjusted income. The returns to the various inputs that could be obtained from either reallocation of resources or increased use of resources, i.e. expanding production. Normally, this would conclude the analysis. However, as noted above, it is possible to analyze the implicit management input statistically. This section discusses the breakdown of the residual or error sum of squares in an attempt to isolate the effect of management.

The data used in this portion of the analysis does not include all of the observations that were included in the regression analysis. Only those ranchers who cooperated for the entire period were included in the management analysis. The total number of observations for this analysis was reduced to 72 from 101. In other words, eighteen ranchers supplied information for all four years of the study period and these were the ranches used in this analysis.

As will be recalled from Chapter 3, Section D, the residual sum of squares for this analysis was computed by this formula:

$$\text{I.} \quad \sum_i \sum_j ((Y_{ij} - Y_{.j}) - b_1(X_{1_{ij}} - X_{1_{.j}}) - \ldots - b_n(X_{n_{ij}} - X_{n_{.j}}))^2 \; .$$

These squared residuals were broken down into two separate parts. Expression II estimated $(4S_2^{\;2} + S_1^{\;2})$ and expression III estimated the random effects, $(S_1^{\;2})$.

$$\text{II.} \quad 4 \times \sum_j ((Y_{.j} - Y_{..}) - b_1(X_{1_{.j}} - X_{1_{..}}) - \ldots - b_n(X_{n_{.j}} - X_{n_{..}}))^2 .$$

$$\text{III.} \quad \sum_i \sum_j ((Y_{ij} - Y_{i.} - Y_{.j} + Y_{..}) - b_1(X_{1_{ij}} - X_{1_{i.}} - X_{1_{.j}} + X_{1_{..}}) - \ldots - b_n(X_{n_{ij}} - X_{n_{i.}} - X_{n_{.j}} + X_{n_{..}}))^2 \; .$$

In Tables III and IV, expression II estimated the sum of squares ascribed to the Between Farms effect and expression III estimated the Random error sum of squares.

Two estimates for the effect of management were obtained. The first estimate was based on all of the input variables except machinery investment. In other words, the error sum of squares was determined by the pooled regression coefficients and included seven of the original eight independent variables. The second estimate was obtained after the elimination of livestock and machinery investment.

The desire for two estimates was based on the fact that since livestock investment was not only the most powerful input but also highly correlated with a number of other independent variables this input might have an adverse influence on the analysis. The effects of livestock investment can be seen in Table I, page 43, and the correlation matrix in appendix Table I shows the intercorrelation.

Since the regression coefficients were pooled estimates obtained from a subset of the original data, cursory comparisons were made between the subsamples and the sample to see how closely the estimates from the subsamples approximated those obtained from the sample. The estimated adjusted income means were quite similar. The sample estimated mean income to be approximately $17,970 and the subsample estimated it to be $17,250. However, this small difference belies the difference in coefficients, particularly for the first set of regression coefficients. Of the seven variables used in the first estimate of management effects only two coefficients of regression are within one standard deviation of the coefficients obtained from the entire sample and neither of these coefficients were significantly different from zero. The first subsample regression also had negative coefficient problems. Not only was range negative, but it was also significant at the .10 level. Land was also negative in the subsample regression. Perhaps the most peculiar aspect of this regression was a negative constant term.

In contrast, the second subsample regression estimated a function that was much closer to its sample counterpart. Only the coefficient for current operating expenses as estimated from the subsample was not within one standard deviation of the sample estimate, but even this variable was within two standard deviations. The coefficient of determination for the subsamples were slightly higher than the sample.

The regression coefficients, constant terms and coefficients of determination for the two subsamples are listed in Table III in the appendix.

Using expressions II and III above, where the regression coefficients were the pooled regression coefficients, the error sum of squares was separated into two parts. Tables III and IV contain the results. Table III contains the results from seven independent variables. Table IV is based on six independent variables. This presentation of data is straightforward except for the total number of degrees of freedom. In this case the degrees of freedom were determined by (n - (a - 1) - 1), where (n) is the number of observations and (a) is the number of years covered by the data.

While both F-tests proved to be significant, the second estimate was highly significant. This test was made to see if the effects of management were significant. The difference between the two sets of estimates is amplified by comparing the respective estimates of the standard deviations. Since there is a relatively large difference between the estimates, a problem arises in determining the reason for the difference and which is more accurate. Theoretically, with a reasonably large coefficient of determination the predictive value of the function will not be adversely affected by problems of intercorrelation among the independent variables. On the basis of this, it would seem logical that analysis I would produce the most accurate estimates. If this is true then it would seem that management is not as important as might be expected, at least in relation to the effects of random influences. However, extreme care must be used in assessing the effect of management because the actual range that is expected to include 68% of the observations around the mean, assuming equality of inputs, is \$15,350 to \$19,380.

The assumption of equality of inputs is highly unrealistic. So in an attempt to make it unnecessary, the following comparative method is proposed. In breaking down the residual into random and management effects, the effect of management was estimated by: $4\left[\sum_j((Y_{.j} - Y_{..}) - {}_i\, b_i\,(X_{i.j} - X_{i..}))^2\right]$. This is the same as comparing the farm average to the overall average. By averaging over four years the random effects tend to be neutralized.

TABLE III

Management Analysis I

with Seven Independent Variables

Source of Variation	Sums of Squares	D.F.	Expected Mean Squares	Variance	F Value
Regression	5.14955	7			
Between Farms	.03634	17	$4S_2^2 + S_1^2$	.018019	2.33*
Random	.33952	44	S_1^2	.007717	
Total	5.79816	68			

TABLE IV

Management Analysis II

with Six Independent Variables

Source of Variation	Sums of Squares	D.F.	Expected Mean Squares	Variance	F Value
Regression	4.90417	6			
Between Farms	.65085	17	$4S_2^2 + S_1^2$	.038285	7.09**
Random	.24314	45	S_1^2	.005403	
Total	5.79816	68			

TABLE V

Management and Random Standard Deviations

	S_1	S_2
Analysis I	.08784	.05073
Analysis II	.07351	.09067

*F test shows ratio to be significantly different at .05 level.

**Difference significant at .01 level.

Given this neutralization, it follows that by putting the logarithms of the average inputs for several years from a ranch into the first within years regression equation (see Table III in the appendix). A comparison of the results of this calculation and the actual average income should give an estimate of the management effect. If the difference between the logarithm of the actual average income and the estimated income from the equation is greater than the standard deviation for management (.0507 for analysis I) the manager of that ranch would be considered to be quite good or quite poor depending on whether the actual average income is greater or less than the estimated income. There may be an upward bias in the estimated income caused by the competency of the management in the allocation of resources, but this should only add strength to the declaration of competence. The reverse situation would hold true for the incompetent manager. There is the problem that moving away from the mean the standard deviation would increase; however, there is the possibility that the two biases might provide countervailing effects and produce an unbiased estimate of management.

Although the management effect in the absolute level of inputs is included in the estimated income from the equation, there is considerable opportunity for the effect of management to appear in the composite variables such as current operating expenses and machinery maintenance. The timing of activities would also be included in this effect. In other words, the ability of the manager to utilize efficiently the inputs in the composite variables is measured by the deviation of the average actual income from the estimated income that was obtained by substituting his average input levels into the equation.

The influence of random effects can also be measured from the average income. Using the adjusted mean income as an example, only 68% of the yearly incomes would be between $14,080 and $21,120. In other words, a rancher with an average income of $17,250 could expect 68% or approximately seven yearly incomes within that range out of every ten years, assuming constant ranching conditions. Two possible causes for this relatively wide range in random fluctuations are weather and cattle prices.

The corresponding ranges as obtained from the second function for management and random effects are $13,970 to $21,250 and $14,500 to $20,430, respectively. These ranges were estimated from the mean value of income. The use of these estimates is the same as that outlined above. It is believed that, on the basis of the coefficients of determination, the results presented in Table III may be more accurate. However, the regression equation that provided the coefficients for the results in Table IV may be more useful than the first equation in helping the weaker manager in providing the guidelines for allocating resources more efficiently. This is because the second analysis, as presented in Table IV, has more significant coefficients, i.e. significantly different from zero.

After estimating the effects of management, marginal value products can be computed in the manner used above in the original regression analysis. These marginal value products would provide an indication of what adjustments in resource allocation would be necessary to obtain a greater income.

Chapter 5

SUMMARY & CONCLUSION

This thesis contained the results of, essentially, two regression analyses. The results of the first analysis which were based on the Cobb-Douglas form of estimation were presented in Tables I and II. Based on these results, four of the input variables, current operating expenses, range costs, machinery maintenance and livestock investment, were shown to be the inputs which would provide the best marginal returns for each additional dollar invested. Land and labor were low in terms of the marginal value product, but not unduly so. The marginal value product for water was not only low, but it was also weakened by a large standard deviation which meant that no valid statements could be made about the use of water for irrigation. Consequently, it was not possible to achieve, totally, the objective of marginal value products for all the natural resources that are used in agriculture in the study area.

The second analysis used 72 of the original 101 observations to separate the effects of management out of the residual sum of squares and establish bounds by which the effects of management might be determined. Tables III, IV and V contained the results of the analysis. It was indicated that 68% of the observations on adjusted total income would lie within the range, $15,350 to $19,380, if equality of inputs was assumed. However, these results were based on the mean income. A proposal was made as to how these bounds might be used by individuals in judging their management ability and then how the same functions could be used in adjusting resource allocation so as to maximize income.

The final result has been two sets of guidelines. One set pertains to the ranchers in the study area in that it provides a method of estimating management ability and also indicates the factors of production which would bring about the largest increase in income through greater use, in general terms. Specific suggestions cannot be made from this type of analysis and such suggestions were not an objective in the analysis. The second set of guidelines pertains to the management of natural resources. It has not been intended that management decisions would be made in this study, however, it will provide the basis for rational decision making by those charged with the responsibility of administering the use of public resources.

BIBLIOGRAPHY.

BIBLIOGRAPHY

Bradford, Lawrence A. and Glenn L. Johnson. Farm Management Analysis. New York: John Wiley and Sons, Inc. 1953.

Calef, Wesley. Private Grazing and Public Lands. Chicago: The University of Chicago Press. 1960.

Cochran, William G. and George W. Snedecor. Statistical Methods. Ames, Iowa: The Iowa State University Press. 1967.

Fox, Karl A. Intermediate Economic Statistics. New York: John Wiley and Sons, Inc. 1968.

Heady, Earl O. "Production Functions from a Random Sample of Farms," Journal of Farm Economics 28:989-1004, November, 1946.

________ and John L. Dillon. Agricultural Production Functions. Ames, Iowa: Iowa State University Press. 1961.

________, Glenn L. Johnson and Lowell S. Hardin (Eds.). Resource Productivity, Returns to Scale, and Farm Size. Ames, Iowa: The Iowa State College Press. 1956.

Huffman, Roy E. Irrigation Development and Public Water Policy. New York: The Ronald Press Co. 1953.

Johnston, J. Econometric Methods. New York: McGraw-Hill Book Co. 1963.

Klein, Lawrence R. An Introduction to Econometrics. Englewood Cliffs, N. J.: Prentice-Hall, Inc. 1962.

Lekachman, Robert. A History of Economic Ideas. New York: Harper and Row. 1959.

Rasmussen, Knud. Production Function Analyses of British and Irish Farm Accounts. Sutton Bonington, Loughborough, England: University of Nottingham School of Agriculture. 1962.

Riggs, Fletcher E. and George S. Tolley (Eds.). Economics of Watershed Planning. Ames, Iowa: The Iowa State University Press. 1961.

U.S. Department of Commerce. 1964 United States Census of Agriculture. Vol. I. Part 39. Washington, D.C.: U.S. Government Printing Office. 1967.

U.S. Department of the Interior. Challis Project. Boise, Idaho. March, 1964.

Wilsie, Carroll P. Crop Adaptation and Distribution. San Francisco: W. H. Freeman and Co. 1962.

APPENDIX

TABLE I

Correlation Matrix
for
101 Observations

	Land	Labor	Machinery Investment	Livestock Investment	Water	Current Operating Expenses	Range Expenses	Machinery Maintenance & Depreciation	Income
Land	1.000	.630	.664	.762	.187	.522	.236	.695	.697
Labor		1.000	.651	.779	.427	.589	.254	.808	.780
Machinery Investment			1.000	.769	.538	.496	.425	.853	.720
Livestock Investment				1.000	.267	.677	.520	.792	.380
Water					1.000	.377	-.021	.459	.416
Current Operating Expenses						1.000	.195	.576	.755
Range Expenses							1.000	.276	.360
Machinery Maintenance & Depreciation								1.000	.801
Income									1.000

TABLE II

Management Analysis Matrix

	Farm							Yearly Average	
Year	1	2	3	4	...	17	18		
1	Y_{11}						$Y_{1,18}$	$Y_{1.}$	4.2447
2		Y_{22}					$Y_{2,18}$	$Y_{2.}$	4.2366
3			Y_{33}				$Y_{3,18}$	$Y_{3.}$	4.2926
4				Y_{44}			$Y_{4,18}$	$Y_{4.}$	4.1730
Farm Average	$Y_{.1}$ 3.9017	$Y_{.2}$ 4.6220	$Y_{.3}$ 4.5396	$Y_{.4}$ 3.9898	...	$Y_{.17}$ 4.0192	$Y_{.18}$ 3.9561	$Y_{..}$*	4.2367

*Overall mean.

TABLE III

Within Years Regression Coefficients

	Function I	Function II
Land	-.05078 (-.7136)*	.13231 (2.0387)
Labor	.12776 (.78218)	.32494 (1.8957)
Livestock Investment	.71746 (4.2365)	
Water	.08134 (1.4663)	.021729 (.98702)
Current Operating Expenses	.11734 (3.0633)	.19989 (3.4686)
Range Expenses	-.03096 (-1.7682)	.23232 (1.6151)
Machinery Maintenance & Depreciation	.13076 (1.1051)	.35349 (3.2196)
Coefficient of Determination	.88053	.85048
Sum of Regression Coefficients	1.0929 (.822)**	1.0556 (.475)**
Constant Term	-.157576	.139346

*t-value - difference from zero.

**t-value - difference from one.