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An econometric analysis of economies of scale and optimum size of independent sugarcane farms on the Hilo Coast

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University of Hawaii, 1987

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AN ECONOMETRIC ANALYSIS OF ECONOMIES OF SCALE AND OPTIMUM SIZE OF INDEPENDENT SUGARCANE FARMS ON THE HILO COAST

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN AGRICULTURAL AND RESOURCE ECONOMICS

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ABSTRACT

The number of independent non-plantation sugarcane farms in the State of Hawaii significantly decreased following the expiration of the 1948 Sugar Act on December 31, 1974, from 510 farms in 1974 to 141 in 1985.

Because of concern regarding the decline in the number of sugarcane growers and the substantial variation in costs of production among them, a research project on estimating economies of scale and optimum size of independent sugarcane farms on the Hilo Coast was undertaken. It was assumed that a study comparing the performance of farming operations among growers might enhance the decision making process, lead to an improvement in overall efficiency and increase opportunities for viable farming operations.

The objectives of the study are to estimate, analyze and evaluate various aspects of economies of scale and optimum farm size of the independent sugarcane growers.

Several econometric models are used in the study. The translog cost function measures scale economies as a relationship between total cost, output and prices. This function under its restrictive form and various assumptions of homotheticity and unitary price substitution effects identifies both economies and diseconomies of scale.

The Cobb-Douglas production function with variable

technologies explains economies of scale as it relates output to labor, land and capital inputs. By investigating the effects of capital on output and selected factors of production, it was found that capital expansion could benefit larger producers through economies of scale. As anticipated, smaller producers are less responsive to capital expansion and diseconomies of scale occur at lower levels of production.

The quadratic function shows increasing and decreasing economies of scale between average cost and increasing output and identifies the optimum level of output and farm size at which independent sugarcane growers could operate their farms efficiently. This function shows that average costs decrease as farm size increases, thus also indicating economies of scale. It also provides a basis for estimating optimum farm size by means of differentiating the equation. The results of the quadratic function indicate that shifts in minimum cost and optimum production levels make it difficult for larger producers to remain in business. Many smaller sugarcane growers, on the other hand, can continue production even though marginal losses occur through the utilization of unpaid family labor and subsidies from off-farm employment.

The results of the empirical analyses indicate that

economic efficiency can be attained by expanding farms to higher levels of production up to specified sizes, depending on the econometric function utilized. In recommending ranges of economic efficiency as defined by economies of scale, the translog cost function was found to be more acceptable than the quadratic function in the analyses. Since the translog cost function shows that economies of scale are present for farms of up to 50 acres in size, independent sugarcane growers producing less than 50 acres could consider expansion to increase efficiency. The research findings indicate, on the other hand, that expansion of farms of 50 acres or greater would probably not result in greater efficiency.

Since no one method provides conclusive information on all possible explanations of economies of scale and optimum farm size, it is recommended that further research be carried out on comparative studies of these and other types of econometric models. Objectives for further research should focus on determining which methodologies and types of data are best suited for estimating economies of scale and optimum farm size.

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CHAPTER I

INTRODUCTION

In recent studies conducted by Holderness, Vieth, Scott and Briones (1979, 1982) on the economic viability of independent, non-plantation sugarcane farms on the Hilo Coast, the findings indicated that there was a great variation in the size of these farms. Acreage harvested in 1977 and 1980 ranged from one acre to more than 500 acres per grower. Such a wide variation in size suggests vast differences in the organization and management of sugarcane production.

The 1979 study, which was based on primary data from 66 independent sugarcane growers, showed that there was a substantial variation in costs of production among four size groups of independent sugarcane farm operators. Cost per acre was lowest for the larger farms of more than 160 acres and highest for smaller farms of less than 10 acres. The average production cost for the larger farms was $951 per acre compared to $1,122 for the smaller farms. The two mid-sized groups showed average costs of $976 per acre for farms with 10-49.9 acres and $978 per acre for farms of 50-159.9 acres.

The cost differences by farm size indicate potential economic benefits through economies of scale and optimum

farm size to independent sugarcane growers on the Hilo Coast. Thus, a study comparing the performance of farming operations with those of other growers having similar as well as different sizes and types of units could lead to an enhancement of the decision making process and an improvement in overall efficiency.

1.1 BACKGROUND

Most independent sugarcane growers cultivate small parcels of land, which in earlier years were not considered suitable to be placed under the direct management of large plantations. Presently, however, many of these same areas are adaptable to plantation use because of the development and availability of modern farming equipment. Nevertheless, a large number of independent growers have continued cultivating sugarcane on their own land as well as on leased land.

Management decisions for the independent farms are made by individual growers, although many obtain assistance from the Hilo Coast Processing Company (HCPC). The HCPC processes and markets sugar for the United Sugarcane Growers Cooperative (USGC) of which most independent growers are members. Contractual arrangements between the growers and the HCPC vary in accordance with local conditions. Because there exists some dependency on the mill, growers continue to coordinate their efforts with the HCPC in cultivating and

harvesting their sugarcane.

Although the HCPC has enabled small growers to compensate for lack of economies of scale, the majority of growers have found it difficult to continue their farming operations. In order to understand the underlying reasons, it is necessary to review the major factors influencing the independent sugarcane growers' decisions to abandon their small farms.

1.2 OVERVIEW OF THE PROBLEM

The number of independent sugarcane farms in Hawaii diminished significantly following the expiration of the 1948 Sugar Act on December 31, 1974, which resulted in less control over sugar imports and prices. Prior to the weakening of the price support system, 510 independent growers farmed small areas of land throughout the State, primarily along the Hilo Coast of the Island of Hawaii. By 1977, there were 504 left, of which 312 were members of the USGC. The total number of independent growers further decreased to 365 in 1980 and 141 in 1985, of which only 110 marketed their sugarcane through the HCPC.

Several significant factors influenced the reduction in the number of independent growers. They may be classified into the following categories:

First, the cost of machinery may be considered one of the most important factors. Mechanization of the farming

enterprise was costly relative to the size of the operation. Because of the small sizes of many farms, growers were unable to take advantage of modern technology, making it difficult to substitute capital for labor. Most independent sugarcane growers custom contracted equipment from dealers who provided specialized field operations requiring the use of larger farming implements and machinery. Because of the high costs of custom contracting, many smaller sugarcane growers had to discontinue their farming operations.

Credit liability was another factor that affected the reduction in the number of independent sugarcane growers. During the period of low sugar prices, many individual growers accumulated unpaid loans in excess of $20,000. Rather than increase the amount of indebtedness on their loans, farmers abandoned cultivation of sugarcane to obtain more reliable employment. Growers who continued to cultivate sugarcane as independent farmers often worked elsewhere to adequately support themselves.

Environmental factors also imposed physical constraints on efficient growing and harvesting of sugarcane. The mean annual rainfall in the production areas of independent growers was somewhat excessive and extreme variations in rainfall occurred from time to time. Due to heavy periodic rains, it often became impossible to meet production deadlines, especially when small producers depended on

others to harvest and mill their sugarcane. These problems resulted in high costs to the independent sugarcane growers.

Topography and distance also affected costs of production and contributed to the decrease in the number of independent sugarcane growers. The fields of small farms on which sugarcane was grown were mostly sloping, thus requiring more time to cultivate, fertilize and provide other factors of production in field operations. Since most small fields were often located away from the growers' place of residency, fertilizer, herbicides, equipment and other inputs had to be transported at considerable distances to individual farms from a centralized location. Once the sugarcane was harvested, it had to be moved from the fields to the processing mill which was as far as 20 miles distant. Combination of the distances traveled and the high cost of fuel considerably reduced the earnings of sugarcane growers.

The management of very small parcels of land by independent sugarcane growers was another factor limiting growth and stability. Approximately 90 percent of the growers during the period from 1977 to 1980 raised sugarcane on farms of less than 50 acres.

Farmers faced problems in timing of delivery during harvesting and processing of sugarcane because of the lack of adequate coordination between themselves and mill

management. Smaller fields, although often harvested together, complicated field scheduling and increased record keeping at the mill.

1.3 PURPOSE OF THE STUDY

Although there were many influencing factors that contributed to the reduction in numbers of independent sugarcane farms in past years, the Hawaiian Sugar Planters' Association (HSPA) reports indicate that historically the most important cause accompanying these factors was the significant loss in net farm income. This resulted especially during a period when sugar prices were below costs of production. Since these factors are still prevalent throughout the industry, it is crucial at this time to determine the probable effect that increased efficiency in production might have on keeping the remaining independent sugarcane farmers in business.

A study on economies of scale and optimum farm size would greatly benefit independent sugarcane growers. It would provide an understanding of their economic position within the framework of the proposed analysis. As a result, independent sugarcane growers could then make better decisions regarding the continuation or discontinuation of their farming enterprises.

1.4 HYPOTHESES

Historically, there were several factors which adversely affected production efficiencies of independent sugarcane growers on the Hilo coast. Some of these factors were uncontrollable, such as environmental conditions, topography and distance traveled between areas of production and the milling site. Certain internal efficiencies were also unattainable to small producers. These included capital improvement through mechanization and better management of very small parcels of land by independent sugarcane growers.

Because adversities and business failures were encountered by all sizes of independent sugarcane farms on the Hilo Coast, it is hypothesized that there is no relationship between farm size and economies of scale. As farm size increases, there is no corresponding increase in efficiency as measured in product output. As a result, it is further hypothesized that the optimum size farm does not exist at which minimum average costs of production can be attained.

1.5 OBJECTIVES OF THE STUDY

The objectives of the study are to estimate, analyze and evaluate various aspects of economies of scale and optimum size of independent sugarcane farms on the Hilo Coast. The statistical procedure utilizes econometric models for determining the various cost relationships for different sizes of farms. Total cost as well as average cost of these farms are defined as the dependent variables and factor prices and output of the farming operation as the independent variables. The primary statistical technique for explaining these relationships is a multivariate regression model which jointly estimates a transcendental logarithmic cost function and selected cost share equations by means of a simultaneous equation system. Other models include a modified Cobb-Douglas function and the quadratic form of an econometric equation.

The transcendental logarithmic function provides information on economies of scales as they relate to total costs of production as well as to elasticities of price substitution. Economies of scale refer to changes in either total or average costs that result from increases in farm operations measured in output or in prices of factors of production. The modified Cobb-Douglas model is a special form of the conventional Cobb-Douglas function which utilizes a capital intensity index that provides ranges of variable cost elasticities and scale economies. Lastly, the

quadratic function estimates the minimum average cost of production and optimum size of farm operation. Optimum farm size refers to the level of output at which minimum cost occurs. Output as it pertains to sugarcane production is measured in tons.

1.6 AREA OF STUDY

The geographic location of the study is confined to the growing area of independent sugarcane producers on the Hilo Coast. This includes 25,000 acres stretching about 18 miles northward out of Hilo and extending approximately 5 miles upward from the coast on the slopes of Mauna Kea (Figure 1). Along with the independent sugarcane growers, the Mauna Kea Sugar Company, one of the large plantations, also processes its sugarcane through the HCPC, but it is excluded from the study. Although the study is limited to members of the United Sugarcane Growers Cooperative (USGA), its findings can be extended to other independent growers throughout the Hilo Coast on the Island of Hawaii.

1.7 STRUCTURE OF THE STUDY

The study is organized into five chapters. The first chapter presents the background, overview of the problem, purpose, hypotheses, objectives and area of the study. The second chapter is devoted to a review of literature relating to economies of scale and optimum farm size. It also

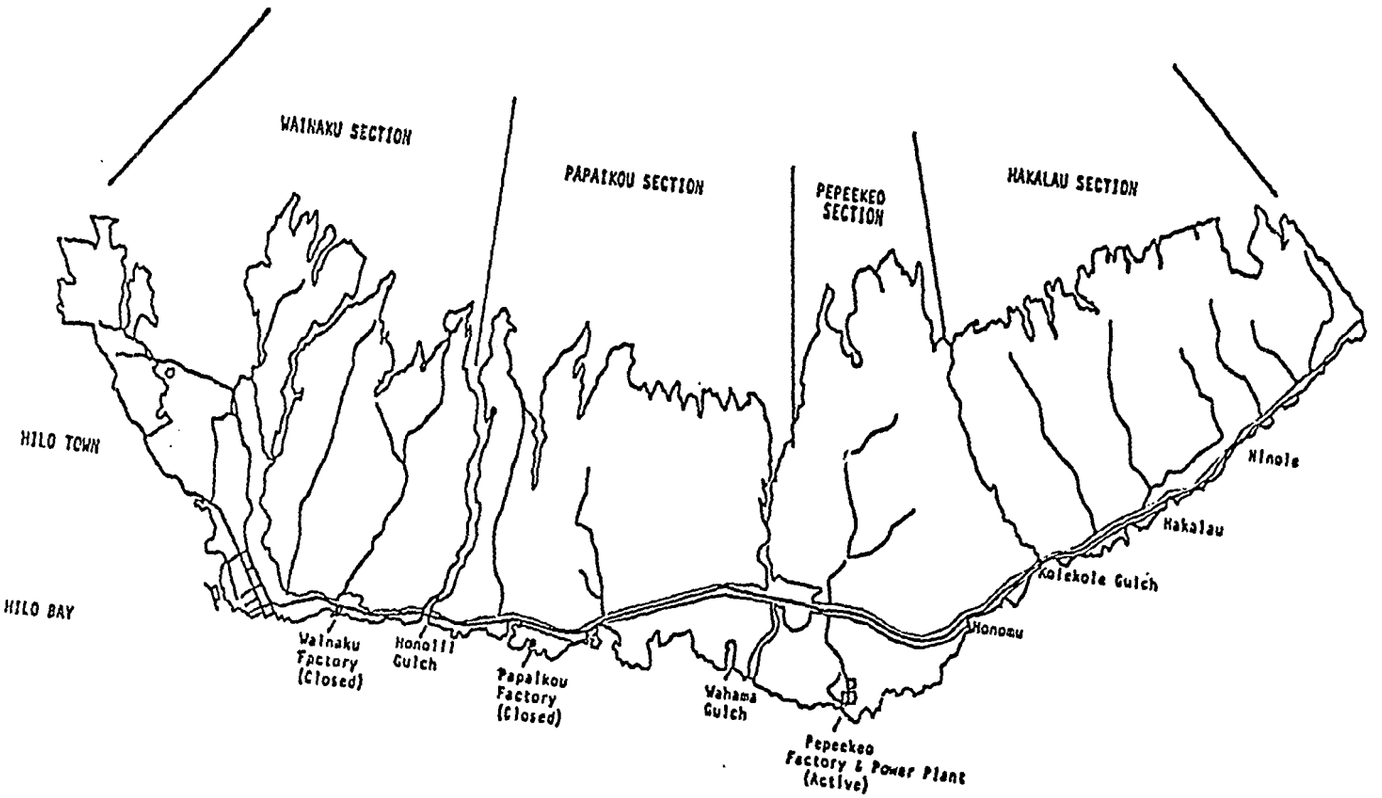

FIGURE 1.1. Growing Area for Hilo Coast Processing Company.

includes a discussion of economic models and empirical studies used for estimating both economies of scale and optimum farm size. The third chapter discusses the methodology and analytical framework of the study. The section on methodology includes the rationale for selecting the econometric approach. It also examines the structural and functional forms of the models, the estimation procedures, assumptions of the models and statistical tests of significance as well as the source and construction of data as they relate to economies of scale and optimum farm size. The fourth chapter presents and analyzes the empirical results of the study. The fifth and final chapter presents the summary and conclusions of the study, including implications for policy recommendations.

CHAPTER II

REVIEW OF LITERATURE

In response to the Hawaii State Legislature House Concurrent Resolution 99 (1978), the College of Tropical Agriculture and Human Resources, University of Hawaii, has monitored the economic viability of independent, non-plantation sugarcane growers since 1978. Reports were published in 1979 and 1982 on the production and processing costs of sugarcane grown along the Hilo Coast on the Island of Hawaii.

The 1977 study provided an analysis of production costs and revenues, classifying independent sugarcane growers into four size groups of less than 10 acres; 10-49.9 acres; 50-159.9 acres; and 160 acres and over. The report also projected costs of growing sugarcane and processing raw sugar for the years 1978-1984. It concluded that the three larger size groups were economically more viable than the smallest group.

The second study also separated independent sugarcane growers into the four size groups similar to the first study, but only for the purpose of identifying the number of growers with the total number of acres planted. The analysis indicated that the costs of independent growers were slightly less than the costs of the plantations, due partly to lower labor costs.

2.1 THEORETICAL CONSIDERATION OF ECONOMIES OF SCALE

The framework for research using economies of scale as an empirical tool is derived from the economic theory of the firm under perfect competition. According to Ferguson (1972), perfect competition consists of an economic model of a market having the following characteristics: (a) each economic agent, such as the firm, is so small relative to the market that it can exert no perceptible influence on price; (b) the product is homogeneous; (c) there is free mobility of all resources, including free and easy entry and exit of business firms ; and, (d) all economic agents in the market possess complete and perfect knowledge.

Although it is understood that no market has been or can be perfectly competitive, a review of the relationship between economies of scale and the theory of the firm under perfect competition is helpful to understand the basis for estimating economies of scale for independent sugarcane growers along the Hilo Coast. Ferguson (1972) pointed out "a theoretician does not select his assumptions on the basis of their realism; the conclusions, not the assumptions, are tested against reality."

Ferguson and Gould (1975) stated that economies of scale occur when, after adjusting all inputs optimally, the unit cost of production can be reduced by increasing the size of the plant. In other words, economies of scale are the reduction in average costs that arise from an increase

in the quantity of resources employed by the firm. Conversely, diseconomies of scale occur when average costs increase with increased size of business.

Economies of scale are usua..ly described in terms of short run and long run concepts. The short run period is long enough to permit changes in output which are technologically possible without changing the farm size. The long run period allows for adjustments of all factors, both in farm size and degree of resource utilization. Thus, short run cost economies result from the more efficient use of a fixed farm size. Long run cost economies, or economies of scale, result from the efficiencies obtained by changing farm size.

There is a need for clarification in the literature concerning the relationship between economies of "scale" and economies of "size". Scale economies generally refer to the proportional increase of all production inputs. Economies of size refer to variable proportions. Ferguson and Maurice (1978) indicated, however, that there is no need to differentiate between the two terms. In their words, "this relation (of economies of scale) applies even when cost curves are not derived by increasing all factors proportionally." In the present study, the term economies of scale is used whether or not factor proportionality is maintained with expansion.

The hypothetical relationship between short run and long run cost curves is depicted in Figure 2.2. According to Leftwich (1976), the short run concept is "a time period so short that the firm does not have time to vary in quantity such resources as land, buildings, heavy machinery and top management." The short run average cost (SRAC) relationships assume one or more of these resources to be fixed in the short run. As the output of the farm increases by applying more variable inputs to the fixed resources, average costs per unit of output decline rapidly at first because fixed costs are spread over more units. However, average costs increase at some point as a result of diminishing returns to the variable input.

A separate SRAC curve applies to each level of fixed resources. For each farm scale, the highest level of efficiency in the use of all variable factors of production is achieved at the lowest point of the SRAC curve representing that scale of the farm. The output level at this point represents the most efficient use for the fixed resources.

Leftwich (1976) defined the long run concept as "a period of time long enough for the firm to be able to vary the quantities per unit of time of all resources used." Since all resources are variable, there is no need to classify resources as fixed or variable. The firm has sufficient time to vary its scale from very small to large.

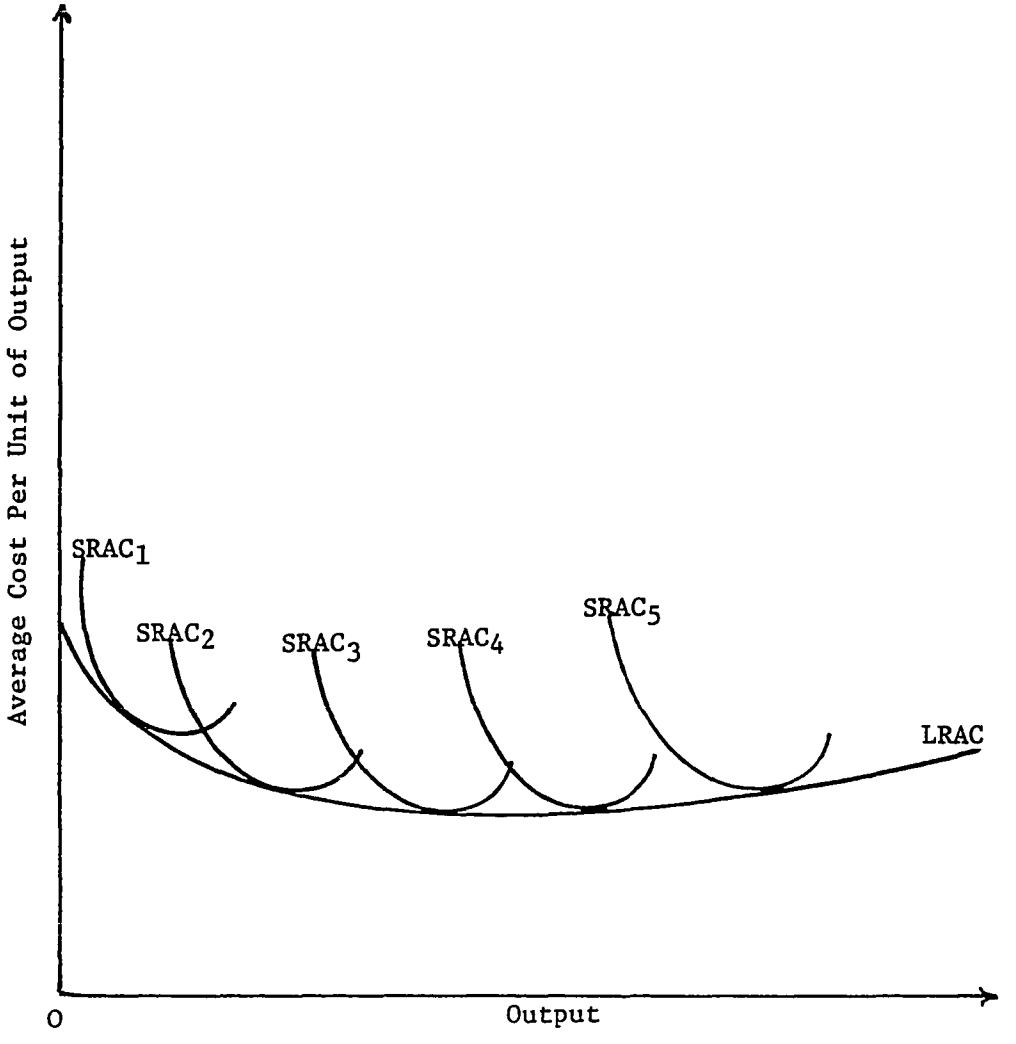

FIGURE 2.1. Hypothetical Short Run and Long Run Average Cost Curves.

Long run average costs (LRAC) in Figure 2.2 are represented by estimating a series of SRAC relationships for different sizes of farms. Since the LRAC curve is made up of very small segments of the various SRAC curves, it can be considered just tangent to all possible SRAC curves representing the different scales that farms could conceivably have. It is referred to as an 'envelope' or 'frontier' curve to the SRAC curves which represents the most efficient method of producing each level of output, considering all possible combinations of variable and fixed resources. The forces causing the LRAC curve to decrease are economies of scale. Conversely, diseconomies of scale exist whenever the LRAC curve increases at the same time output increases.

2.2 THEORETICAL CONSIDERATIONS OF INPUT OPTIMIZATION

The underlying assumption for the economic analysis of independent sugarcane growers along the Hilo Coast is that of profit maximization. In order to maximize profits, the growers must choose the optimum combination of imputs and level of output to produce sugarcane. This decision depends on the total budget available to growers for purchasing inputs as well as the relative costs of these inputs. According to Ferguson (1972), "the problem, therefore, is to determine the particular input combination that minimizes the cost of producing a stipulated level of output."

In the simple case of only two variable inputs, the situation of input optimization may be depicted graphically, as illustrated in Figure 2.3. At given input prices of capital and labor, an entrepreneur decides to produce a level of output indicated by isoquant I. Isocost curves KL, K'L', and K"L" represent an infinite number of isocost curves from which the producer can choose at given input prices. He would want to choose the lowest one that enables him to attain output level I, which is isocost curve K'L'.

Any resource expenditures below K'L', as depicted by KL, are not feasible since it is impossible to produce output I with these resource combinations. Resource expenditures above K'L' are rejected because the producer cannot produce the desired output at least cost. If he produces at either A or B, at the cost represented by K"L", he can reduce his costs by moving along I to point E. This is the point of optimal resource combination by using OK_o units of capital and OL_o units of labor.

According to Ferguson and Maurice (1978), in order to minimize cost subject to a given level of output and given input prices, the producer must purchase inputs in quantities such that the marginal rate of technical substitution of capital for labor is equal to the input-price ratio (the price of labor to the price of capital).

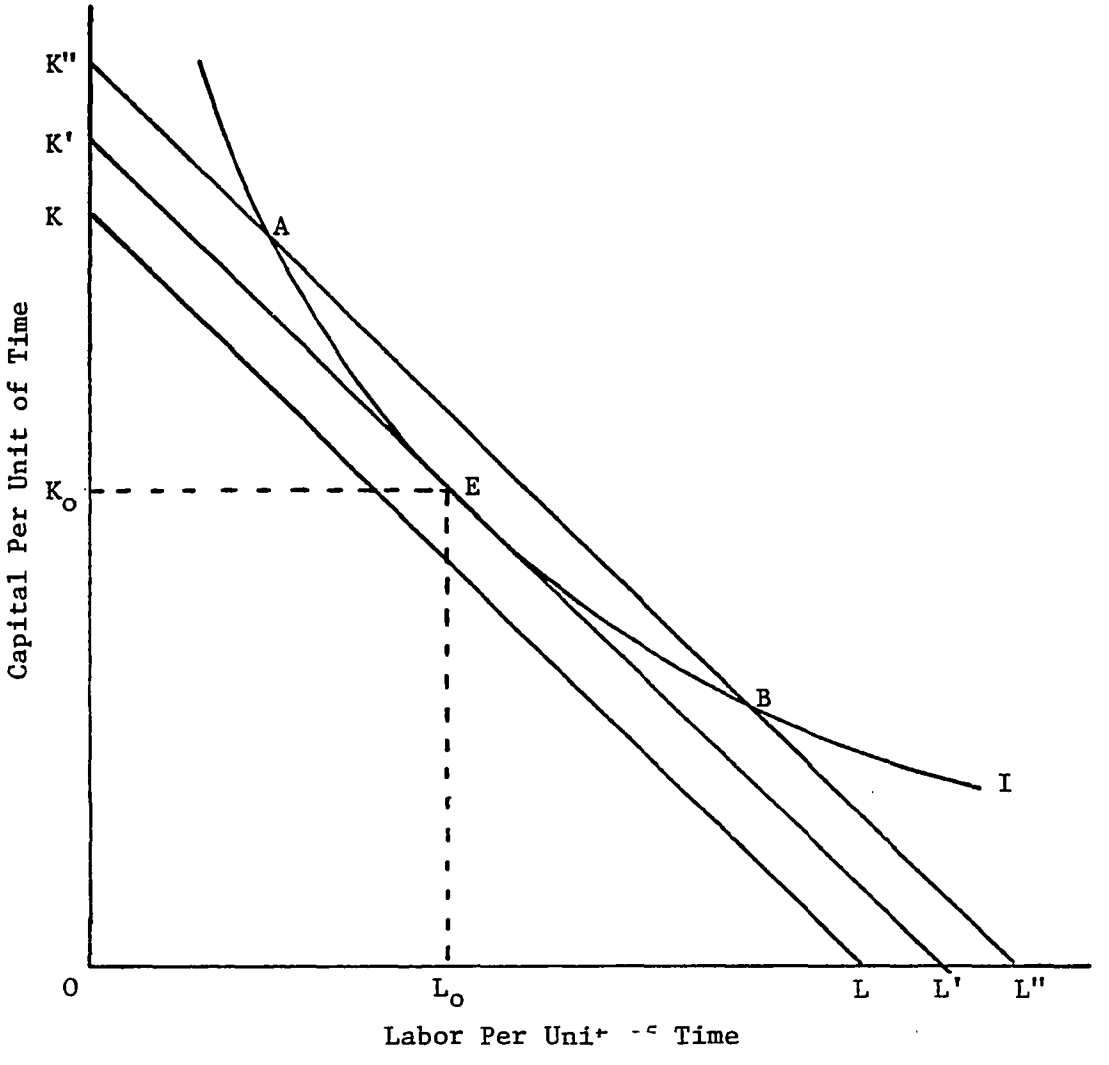

FIGURE 2.2. Optional Input Combination to Minimize Cost Subject to a Given Level of Output.

Thus,

$$MRTS_{K \text{ for } L} = MP_K \text{ divided by } MP_L$$

On the other hand, the producer may be restricted at a fixed amount to spend on purchasing inputs and may wish to attain the highest level of production consistent with the specified amount of expenditures. As previously demonstrated, the entrepreneur produces where the isocost curve representing the amount to be spent is tangent to the isoquant. This is the highest isoquant attainable. Again, the marginal rate of technical substitution of capital for labor equals the input-price ratio.

The producer may also minimize losses at the level of output where short run marginal costs equal marginal revenues. Thus,

$$SRMC = MR$$

At output x, where market price is p in Figure 2.4, equality between SRMC and MR provides minimum losses. At a lower output, MR is greater than SRMC and increases add more to total receipts than to total costs. This reduces losses. Beyond output x, SRMC is greater than MR, which means that increases in output add more to total costs than to total receipts.

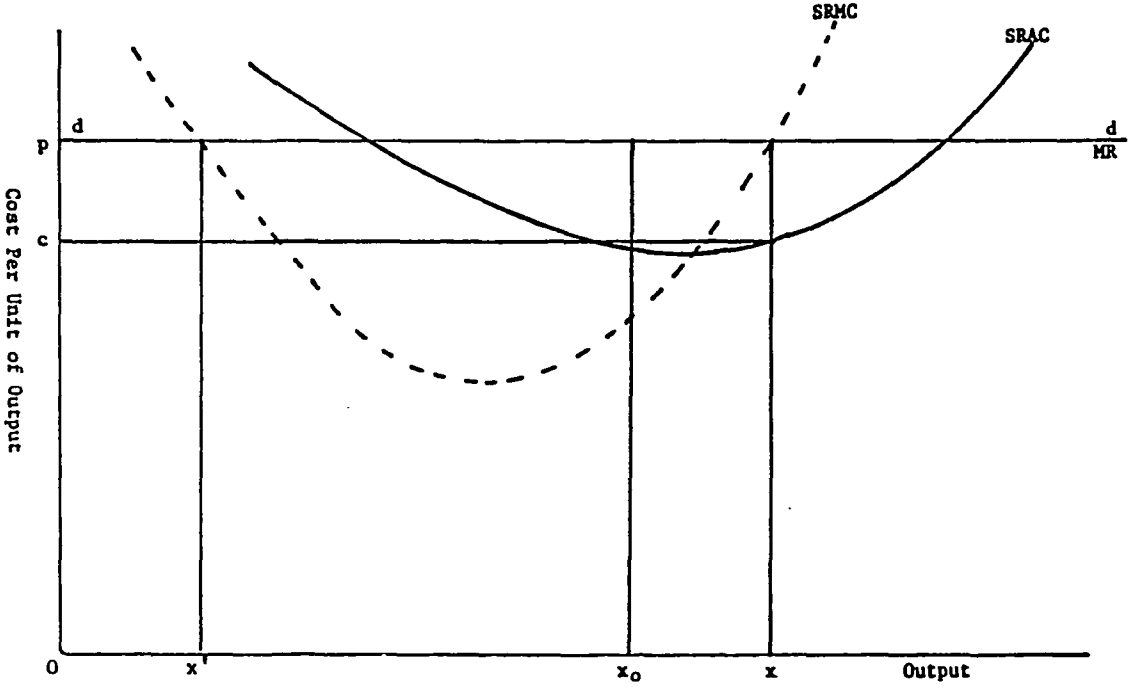

FIGURE 2.3. Relationship between Short Run Average Cost, Short Run Marginal Cost and Marginal Revenue.

The above explanation is a simplified presentation of input optimization. A complete development of this topic with necessary and sufficient conditions for profit maximization or loss minimization can be found in Henderson and Quandt (1971), Varian (1978) or in any of numerous other economic texts.

2.3 METHODS FOR ESTIMATING ECONOMIES OF SCALE AND OPTIMUM FARM SIZE

This section considers various methodologies that are currently available for the study. The discussion also includes the advantages and disadvantages of choosing each method. Once identified and explained, several applied cases found in the literature are presented in the following section. The statistical models chosen for estimating economies of scale and optimum size of independent sugarcane farms on the Hilo Coast are presented in detail in the next chapter.

Methods for estimating economies of scale and optimum farm size may be classified according to the following analytical techniques:

1. Synthetic Firm Approach. Techniques used under this method include budgeting, mathematical programming and simulation models. All of these approaches are well adapted to estimating an industry cost curve under the assumption of a single 'most efficient' technology. According to Anderson

and Powell (1973), the data for these analytical techniques "may be randomly or deliberately selected from actual records and adjusted in some way to yield 'efficient' or 'full utilization of capacity' relationships." Synthetic models, thus, can trace out short run cost-output relationships for different size firms. Long run envelope curves can then be sketched beneath the short run curves.

In the case of a single productive activity carried out by firms of various size levels, the budgeting method may be best adapted to derive the SRAC and LRAC curves. If several productive activities are involved in each of the firms, linear programming models are often used. Simulation techniques are also adapted to estimating average cost curves under certain conditional assumptions.

Several difficulties are common to these methods. It is necessary to determine a set of technical coefficients which describe the transformation of inputs into outputs. The underlying assumptions of these estimates determine the final shape of the cost curves. In general, it is assumed that firms of similar size utilize a common technology and input mix. Because of these reasons, the synthetic firm approach poorly represents reality and hence must be interpreted with caution.

2. The Survivorship Method. Stigler (1958) referred to the method of analyzing economies of scale as the 'survivorship principle'. According to him, the survivor

technique solves the problem of determining the optimum firm size as follows: "Classify the firms in an industry by size, and calculate the share of industry output coming from each class over time. If the share of a given class falls, it is relatively inefficient, and in general is more inefficient the more rapidly the share falls." Simply stated, the size concentration of firms within the industry is estimated at two discrete points in time. The model assumes that the most efficient firms endure and the inefficient firms operating at higher costs are eliminated through competition. If the efficient firms increase in size over time, it is concluded that this may be the result of scale economies.

The advantage of Stigler's method lies in its simplicity and low data requirement. It may be useful in studying industries with few firms or where cost data is difficult to obtain. It is not used in studies where sufficient cost-output data are available. The method is not analytical in that direct inferences are not made about the LRAC curve of the industry.

3. The Farrell Technique. This method makes use of accounting data from individual firms to construct a frontier cost function. It calculates multidimensional efficiency indices from the accounting data and applies these indices to derive the frontier function. The economy of scale question is addressed by comparing the economic

efficiency indices with some measure of firm size.

Although the method separates the effects of scale into production costs and technical efficiency, the common fault of this technique is that it estimates the frontier function from relatively too few observations. As a result, this approach is very sensitive to measurement errors.

4. Classification Analysis. Classification analysis is a nonstatistical means of estimating a few discrete points on the average cost curve. This method also divides the sample firms into groups of different sizes. Average costs are estimated for each size group and plotted on a graph. Comparison of cost-output points is used as a basis to determine if economies or diseconomies of scale exist.

Although this method represents reality, it does not allow rigorous statistical testing between cost and output. It provides only a few discrete points that are assumed to lie upon a LRAC curve. This technique does not estimate the frontier cost function, but it is an estimation of the cost curve which might exist for the average firm within each size group.

5. Statistical Analysis. The application of an econometric function utilizing accounting data from firm records on costs and output is among the most common methods of estimating scale economies. Variance and covariance tests are also included as techniques of statistical analysis.

Since this method makes use of actual cost data from firms that are in production, the results of the analysis are truer representations of reality than those obtained by the preceding methods. Statistical analysis can relate information concerning economies and diseconomies of scale associated with firm management. Furthermore, tests of significance can determine the degree of confidence of these estimates. It is for these reasons that the statistical analysis method is chosen as the analytical tool for the study of economies of scale and optimum size of independent sugarcane farms on the Hilo Coast. As indicated earlier, the specified technique to be used is a multivariate regression model which jointly estimates a translog cost function and selected cost share equations by means of a simultaneous equation system.

The usual problems of applying the statistical analysis method to accounting data exist in this type of analysis. In order to arrive at reliable results, an adequate number of sample observations must be obtained for testing. Similarly, the tests must be representative of the efficient frontier cost function, and not simply average cost curves faced by firms at various size levels. Heteroskedasticity which is a common problem with cross-sectional data and autocorrelation with time series data must be dealt with case by case.

2.4 EMPIRICAL STUDIES

A review of literature in the area of economies of scale and optimum farm size indicates that there has been a vast number of empirical studies on the subject. It would be a massive undertaking to review all of the articles that have appeared in economic journals alone. French (1977) provided a relatively complete review of literature on economies of scale prior to 1974. The review of literature covered in this section, therefore, includes research on economies of scale and optimum farm size published during the past ten years and directs the reader to French for earlier studies.

Chan, Heady and Sonka (1976) determined per unit cost relationships for various machinery combinations and farm situations in north central Iowa, and the effect of these situations on profitability of crop production. The report was concerned with the nature and extent of economies of scale and their effect on smaller and larger farms. The methodology of the study focused on estimating cost functions through the budgeting approach for farms of different crop acreages with various machinery combinations. Both short run and long run cost curves were estimated to determine the nature and extent of cost economies of farm size. Five machinery combinations were selected for farms ranging from 160 to 1,280 acres in size. The major policy implication of the analysis indicated that

the advantage for farm size expansion was related to increasing volume of output rather than reducing costs. Thus, the major part of these benefits would go to the farming sector itself. This means that society, under available technologies, may be unlikely to benefit greatly through lowered food costs from further farm size expansion.

Johnson (1977) analyzed farm budgets from a survey of 60 farms in Saskachewan, Canada. The study centered on three farm sizes: 600 acres, 1,200 acres and 2,400 acres of cropland restricted to cash-grain operations. The major findings of the analysis concluded that the returns to equity and management on owner farms varied from 9.3 percent on small farms to 16.4 percent on large farms. By expanding from a 600 acre farm with 100 percent equity (no land rented) to 1,200 acres with 50 percent equity and 2,400 acres with 25 percent equity, the author suggested that after tax returns to equity and management increased from 7.11 percent to 11.41 and 20.13 percent, respectively. When all costs were considered on a cultivated-acre basis, the 1,200 and 2,400 medium and large farms were producing crops at between $8 and $12 an acre less than the 600 acre small farm.

Hall and LaVeen (1978) surveyed small fruit and vegetable farms in California in order to examine some of the determinants of economic efficiency. A linear

programming algorithm was used to construct non-parametric frontier functions from the data. From these functions grouped with similar scales of operation, measures of technical and economic efficiency were computed. The authors found that the average technical efficiency score for the smaller farms was lower than the average score for the larger farms. This indicated that while inefficiencies did exist for the small farms, they were not as large as the inefficiencies that were unrelated to size. The analysis did suggest that price inefficiency was more important than technical inefficiency in explaining overall inefficiency of either type. The study contained an interesting methodological component having used agricultural census data to construct costs and returns of various crop farms in different size classes. The data were adjusted to make different farm sizes comparable. The authors concluded that economies of size were evident in the census data. Their findings indicated that the LRAC curve was relatively flat after initially declining quite rapidly. Hence, these cost curves would fit the general description of an L-shaped curve.

Raup (1978) noted that the guarantee of farm commodity prices affected farms of various sizes differently. He stated that: "conflicting economic forces and public policies have created this threat of economic cannibalism within agriculture in which the strong consume the weak." If

government support prices were high enough to cover the high costs of production, then large producers are encouraged toward further expansion. The author concluded that small producers who cannot afford to expand stop producing.

Gardner and Pope (1978) disagreed with Raup's thesis: "We are not satisfied that either the theoretical or empirical rationale is adequate. It is clear that price supports and other government policies reduce risk by truncating the lower tail of the probability distribution of returns. However, the link between these effects and increased scale has never been measured in a ceteris paribus world. The impact of price supports might well have been output-increasing, but whether or not the distribution of benefits favors large farms or are proportional to size has never, to our satisfaction, been demonstrated."

Matulich (1978) analyzed the sources of efficiencies in large scale dairying in the Chino Valley of California. The study estimated both long run and short run cost curves, using the economic engineering approach of analysis. Fourteen single capacity herds were used ranging from 355 to 1,200 cows per herd. The LRAC curve was derived as a discontinuous frontier of the lowest points on the SRAC curves. The author found substantial economies of scale among different size herds. Milking automation and better capacity utilization explained the increases in efficiency.

Khan and Maki (1979) made use of the Lou-Yolopoulos model which utilizes the Cobb-Douglas function to derive values of technical and price efficiency parameters in order to identify and isolate the difference between large and small farms. These estimates were based on farm-level data collected from a sample of 728 farms in the Punjab and Sind provinces of Pakistan. Large farms were identified as those of 12.5 acres and over, which included three-quarters of all farms in the sample. The authors tested various hypotheses and provided results in all cases. They found that large farms were 18 percent more efficient than small farms in the Punjab province and 51 percent in Sind province. It was also shown that both large and small farms maximized profits in the Punjab province, while in the Sind province large farms maximized profits but small farms paid labor more than their marginal product. The authors recommended that land consolidation and other policies designed to encourage large farms should be undertaken if efficiency is the major consideration.

Finley and Retzlaff (1979) used budgeting methods in a study on economies of size in midwest hog operations. In comparing the costs of various sized farrowing pens for hog enterprises, six fixed capacity units were considered, ranging from eight to 200 sows per unit. Farrowing intensity was also varied from two to four to six litters per year. The authors found that as capacity and intensity

increased from 110 to 830 hogs, labor per head decreased by nearly 46 percent and total costs by over 18 percent. The report concluded that a small capacity enterprise that operated under very intensive operations was competitive with larger enterprises with lower intensity of farrowing.

Boehlje and Griffen (1979) used simulation techniques to address the financial impacts of price supports on midwest corn producers. The study specified both the financial characteristics and constraints of these farms. In addressing the proposed indexation of government support prices, they concluded that: "The results summarized here indicate that with current price expectations and government program parameters and conservation, inflation rates, the cost-of-production-based support price mechanism could increase land prices drastically within a short period of time. Although all current land owners receive the benefits of the capital gain that would result, the larger equity operator is best able to pay the higher price for additional land. Furthermore, the guaranteed cash flow that results from such a support price program is much greater for the larger, high equity farmer ... so he can utilize more debt to acquire the land and service the debt without impairing his consumption level. Thus, the great majority of the benefits of such a program go to larger, high-equity producers. The numerical results clearly suggest that the financial characteristics of the farm as well as the size of

the farm are important in evaluating the micro and structural implications of government support price programs."

Miller, Rodewald and McElroy (1981) studied farms producing wheat, feed grains and cotton in seven field crop regions of the United States to determine the importance of technical economies of size in the farm sector and to examine how much cost economies may have changed farm structures. Cost efficiency was estimated for four hypothetical farm sizes in each region from data obtained during the 1978 USDA cost of production survey. The economic engineering approach, which utilized a cost minimization linear programming model to estimate farm SRAC curves, was adopted to study economies of size. The LRAC was then estimated by plotting envelope points of tangency on the SRAC curves. The authors found that regional differences existed and cost efficiencies were estimated to be highest in the Southern Plains and lowest in the Mississippi Delta. But all study regions showed the same general economies of size relationships. As farm size increased, per unit costs declined at first and then were relatively constant over a wide range of sizes. It was concluded that most farmers enlarged their operations in search of higher incomes, rather than to increase per unit cost efficiency.

Rao and Chotigeat (1981) reexamined the relationships between the size of land holdings and agricultural productivity for several states in South India. Using pooled data, the study employed the transcendental logarithmic (translog) function to formulate the relationship between output and an arbitrary number of inputs. Estimates of output elasticity with respect to land size for various values of inputs were included in the study. The authors found that capital had a positive effect, and land and labor negative effects on the elasticity of the gross value of output per unit of land. However, it was noted that large increases of capital could compensate for the negative effects and a positive total relation between land size and productivity could be obtained. Large sized farms with capital-intensive techniques could obtain higher productivity with increased land holdings, especially with multiple cropping. The results suggested that larger sized land holdings were not less productive than smaller land holdings. If hired labor were employed in preference to family labor, and if more nontraditional capital as opposed to traditional capital were used, larger sized holdings and higher productivity could be achieved.

Ahmed (1981) contested the concept of an alleged inverse relationship between farm size and land productivity that had previously emerged in economic literature. In

order to examine the various hypotheses that were presented to explain this relationship, he based his study on an agricultural household survey conducted in 1975-76 in the Shahbazpur Union in the Brahmanbaria subdivision of Comilla district of India. To be consistent with previous writers, he examined the relationship between farm size and labor use by means of a logarithmic function. The results of the statistical tests showed that an inverse relationship between farm size and land productivity was, in fact, found. The author argued that the inverse relationship was due to smaller farmers adapting more labor intensive crops and having higher cropping intensities than the larger farmers. The finding added a new explanation to previous hypotheses used to explain the relationship between farm size and labor use.

Richardson and Condra (1981) evaluated four alternative farm sizes of 160 ,320, 640 and 960 acres, for the El Paso Valley area in Texas. This was accomplished with a dynamic farm simulation-linear programming model that incorporated uncertainty in production and marketing activities over time. The linear programming (LP) model was linked to the simulation model, estimating annual production, marketing, financial and income tax activities of a typical farm over a multiple-year planning horizon, to permit the crop mix to change over time. The LP model maximized expected net returns above variable costs, subject to constraints

reflecting acreage allotments for crop and rotation patterns. The authors drew three conclusions from the analysis: (a) that there was a well defined, direct relationship between farm size and/or beginning equity level and the chances of survival and success for farms in the El Paso Valley; (b) that a straight cash-lease farm operation had little chance of survival and success; and (c) that the minimum size and beginning equity situation for success was 640 acres of owned farmland.

Vlastuin, Lawrence and Quiggin (1882) discussed the theoretical, conceptual and estimational issues relevant to economies of size in Australian agriculture. Some of the issues discussed included the effects of technological change on the position and shape of the average cost curve over time, the relationship between farm size and relative economic efficiency, and frontier versus average estimation techniques. Empirical estimates of the extent of size economies were derived from a flexible translog production function using data collected for the New South Wales Wheat/Sheep Zone for the years 1966-67, 1975-76 and 1976-77. Estimation of the production function revealed that, when the relatively fixed inputs of operator and family labor were excluded, the sample exhibited constant returns to scale. When operator and family labor were included, the cost curve exhibited the familiar L shape curve found in earlier agricultural studies. This result

was consistent with existing policies aimed at facilitating rural adjustments by means of farm build-up and greater use of family labor in order to attain the minimum efficient farm size.

Kislev and Peterson (1982) constructed and empirically tested a theory of the agricultural firm which explained the long-term growth in farm size in the United States. The model was based on a set of restrictive assumptions formulated to determine various features of the family farm and to highlight the major determinants of its size. The most specific assumption was based on the fixed quantity of labor in a family enterprise. Consequently, the ratio of the opportunity cost of farm labor to the price of machinery services was the determining factor influencing the size of the farm operation. Applying the model to United States data, the authors virtually explained all of the growth in the machine-labor ratio and in farm size over the 1930-70 period by changes in relative factor prices without reference to technological change or economies of scale. According to the authors, 99 percent of the growth in farm size as measured by acres per farm was explained by their model.

Moghadam (1982) tested the relationship between farm size and productivity of four villages selected from the more advanced agricultural producing regions of Iran. The purpose of the study was to evaluate and compare the

economic performance of individual farms in each case area. Intensive field survey methods were used to measure all farm outputs and factor inputs. Statistical tests of analysis of variance and covariance were applied to the survey findings. These tests examined not only technical input-output relationships, but also the impact of the farm-management system which was represented by a dummy variable. The results of the tests showed that within each village the highest total productivities were observed for medium-size 'peasant' producers. The small size 'peasant' producers showed a lower total productivity, but usually a higher return per unit of land output. The number of 'capitalist' farms included in the survey was usually too small to permit statistical tests of significance. However, the available data suggested an inverse relationship between size and total productivity ratios among the 'capitalist' farms. Comparisons of these farms and the small-scale 'peasant' producers suggested that the smaller size 'capitalist' farms have higher total productivities than the small-scale 'peasant' producers. But, the larger 'capitalist' farmers have total productivities equal to or lower than the small-scale 'peasant' farmers.

Garcia, Sonka and Yoo (1982) attempted to determine differences in economic efficiency for two structural dimensions of a sample of Illinois cash grain producers. The dimensions were the size of operations and the degree to

which land was owned by farmers. The sample consisted of 311 Illinois cash grain farms. Data were obtained from the Illinois Farm Business Farm Management Association records for the year 1977. The major objective of the analysis was to determine the relative economic efficiency of moderate-sized commercial farms of less than 700 acres compared to larger-sized operations of over 700 acres. The model selected for the study was the unit profit function developed by Lau and Yotopoulos (43), which is consistent with the Cobb-Douglas production function. The results of the study indicated that for cash grain farms in Illinois, larger operations were no more economically efficient than moderate-sized farms. Although this may appear contradictory, it was explained by the short run nature of the analyses.

Hanson and Eidman (1983) reviewed the empirical results and assumptions of a simulation model used previously by Richarson and Condra (1981) to evaluate farm size in the El Paso Valley. They concluded that the sensitivity analysis model had potential, but should include "careful empirical validation at all stages of modeling to enhance its credibility." According to these authors, the assumptions of the model appeared too rigid to explain accurately the effects of acreage limitations. The only conclusion to be drawn from the analysis was that "the chance of success increases with equity."

Condra and Richardson (1983) responded to Hanson's and Eidman's criticism by stating that the assumptions for the El Paso study "were generally well found in theory." They pointed out that the results of the analysis were not inconsistent with other studies, provided regional and methodological differences were properly considered.

Carter (1984) used a pooled farm data set to distinguish between alternative explanations of the inverse farm-size productivity relationships in the Indian state of Haryana. The data for the study were from farm management surveys taken during the agricultural years 1969/70 and 1971-72. For each of the three years, 162 holdings were selected through the use of a multistage stratified sampling procedure. The data, pooled across villages, were used to estimate a tranlog regression function where farm size was considered the independent variable and total annual farm output as the dependent variable. The ordinary least squares estimate of 'beta' showed a very strong inverse relationship between farm size and productivity, with per-hectare production declining nearly 40 percent as farm size doubled. The author provided two classes of explanations of the inverse relationship. The first class hypothesized that the observed relationship was a misidentification of factors, such as soil quality and productivity found in small villages. Villages with small holdings having had cheap and abundant labor which allowed

both small and large units to employ more labor per-hectare exhibited higher farm productivity. After controlling for village factors, the inverse relationship would disappear, or at least be diminished. The author concluded that the inverse relationship between farm size and productivity had been found to be "a reflection between small and large farms, rather than a product of sample selection or village factors correlated with farm size."

Williams (1985) examined the relationships between several business and dairy management practices in determining dairy farm incomes for dairy farms in New York State. The author utilized both farm management records and dairy herd improvement records for the study. He analyzed the data by regression techniques using the Maximum R Square Improvement option in the stepwise regression procedure of the Statistical Analysis System. Several measures of size of businesses were used, but the number of cows, total capital invested and total pounds of milk sold were found to be adequate. The larger farms seemed to be more efficient in their use of labor and capital than the smaller farms. Dairy feeding practices were found to be related to milk price, but this relationship might be the effect feeding practices had on fat tests, which was found to be strongly related to milk price. The author concluded that the selected dairy management practices studied did have an effect on dairy farm incomes as indicated by the applied

regression technique.

Doran (1985) discussed the use of a dummy variable in regression analysis to divide the sample size into small and large farms. Earlier studies arbitrarily separated groups of farms by estimating a separate production function for each group. The author noted that this was equivalent to including a dummy variable in a single regression on the whole sample. To modify this approach, the dummy variable (a step-function) was replaced by either a cumulative normal or logistic function. By this means, the researcher could obtain valuable information on whether a small-large categorization was appropriate and, if so, where the division should be made. Doran provided an example of a recent study of Nepalese agriculture from data having consisted of a cross-section of 62 farms in the Rupandehi district of Nepal. Farms of less than 2.5 bighas (4.18 acres) landholding were classified as small and those of at least 2.5 as large. Having used the same variables and data, the nonlinear regression model recommended by the author indicated that the appropriate cutoff between small and large farms should have been at 1.7 bighas (2.84 acres) instead of the arbitrarily chosen value of 2.5 biglas (4.18 acres).

The preceding examples of empirical studies taken from recent authors indicate that an inverse relationship primarily exists between farm size and economic efficiency.

However, there were several scientific studies in literature that demonstrated opposite results. The following articles cited here identify different effects on increasing size other than decreasing costs.

Faas, Holland and Young (1981) selected a simple multiple-year farm income simulation model to estimate net farm incomes of representative farms in the 540,000 acre Columbia Basin Project in central Washington. An after-tax accounting approach was used from data for the 1973-1977 period on average farm prices and yields. The analysis revealed that locally retained income per acre generally decreased as farm size increased. The authors concluded that this was due to the progressive rate structure of the federal income tax system. When the role of irrigation technology was introduced, while increased technology in irrigation practices reduced payments to hired labor, owner-operator's profits decreased for certain cropping patterns. The combined effect of farm size and irrigation technology indicated that the small labor-intensive farm scenario generated 37 to 40 percent more estimated owner after-tax net income per acre than the large farm capital-intensive scenario.

Deolalikar (1981) tested two hypotheses, namely: (a) an inverse relationship was valid for all Indian agriculture, insofar as the small farm sector as a whole was more productive than the large farm sector; and (b) the inverse

relationship was true only of a traditional agriculture and it broke down with technical progress. The methodology included an Ordinary Least Squares econometric equation estimating group and technical specific productivities. Data for the analysis were gathered from cross-sectional regions which covered 272 districts for the agricultural year 1970-71. The author found that the hypothesis of the small farm sector having been more productive than the large farm sector could not be rejected at low levels of agricultural technology, but could be rejected at higher levels. This suggested that the inverse relationship between yields and farm size, although valid for traditional agriculture, could not be assumed to exist in an agriculture experiencing technical change.

Bagi (1981) analyzed the effect of farm size on the economic efficiency of irrigated, partially irrigated and dry farms in Haryana, India. In order to test the efficiency differences between small and large farms, the log-linear Cobb-Douglas production function was estimated. The analysis indicated that the small farms used relatively larger amounts of variable inputs, and produced higher output per hectare as compared to the large farms, irrespective of the extent of irrigation. However, the results showed that the unit cost of production was affected by irrigation. The unit of production on small farms was higher, lower, and almost equal to that of the large farms,

in the sample of 102 irrigated, 99 unirrigated and 119 partially irrigated farms, respectively.

Bagi (1982) in a later study used primary data obtained from a stratified random sample survey in two counties in west Tennessee. The sample consisted of 193 farms divided into crop and mixed farms. These two types of farms were further subdivided into small and large farm groups on the basis of the acreage and the value of gross farm sales. The Cobb-Douglas production function was estimated for each farm group, using the maximum likelihood method. The results showed that both small and large crop farms had almost equal technical efficiency. But, mixed large farms had somewhat higher technical efficiency, as compared to the mixed small farms. However, both small and large farms, classified according to acreage as well as the value of farm sales, had substantial technical inefficiencies, defined as the degree of failure to produce the maximum output from a given level of inputs.

CHAPTER III

RESEARCH METHODOLOGY

In the previous chapter, several methodologies were discussed that are currently available for analyzing economies of scale and optimum farm size. Empirical studies utilizing these techniques were reviewed from literature published over the past ten years. It was noted that each method had advantages and disadvantages, depending on the nature of the problem. In the case of the present study, the method most suited to estimating economies of scale and optimum farm size is the statistical analysis of actual cost data obtained from interviews of the sugarcane growers themselves. Hence, an econometric approach utilizing statistical testing was chosen as the analytical tool for the research methodology.

The principle task in this chapter is directed at specifying the statistical models which identify both their structural and functional forms. Particular decisions to be made include the dependent and independent variables chosen for the econometric equations. Explanations of the estimation procedures, their underlying assumptions and statistical tests of significance are also presented. In addition, the collection of data and their primary source and construction in formulating the models are discussed.

Finally, the variables used in the models are defined in detail.

Three econometric models are chosen to analyze economies of scale and optimum size of independent sugarcane farms on the Hilo Coast, namely: 1) the transcendental logarithmic cost function; 2) the modified Cobb-Douglas function with variable elasticities and scale economies; and 3) the quadratic function. The transcendental logarithmic cost function, otherwise called the translog cost function, identifies the relationship between total production costs and resource prices providing variable scale economies and own-price and cross-price elasticities. The modified Cobb-Douglas function measures variable elasticities and scale economies by means of a capital intensity index which is added to the econometric equation. The quadratic function provides additional information by estimating minimum cost and optimum farm size.

3.1 TRANSCENDENTAL LOGARITHMIC COST FUNCTION

3.1.1 STRUCTURAL FORM OF THE TRANSLOG COST MODEL

In choosing the statistical method for estimating economies of scale and optimum farm size, the relationship which describes the structural form of the translog cost function must first be considered. For this purpose, the production function is specified as:

$$Y = f(K, L, L', D, I, F, O) \qquad (3.1)$$

where

Y = output per unit of time

K = capital

L = labor

L'= contract/custom field work

D = land

I = interest on loans

F = fertilizer

O = other variable inputs

The structure of this relationship is referred to as the primal form in economic production theory. Output (Y) is measured in actual physical units of output; and inputs (K,L,L',D,I,F,O) are similarly measured in physical units of inputs. Since raw data for empirical studies are not always collected in physical forms of measurements, it is difficult to apply the primal approach.

An alternative approach to the primal form in economic theory is the dual or duality approach - the relationships between economic observations which are dual to the physical technology. This approach simply states that technology may be equivalently represented by either the production function or the cost function.

The theory of the dual approach appeared in the early works of Hotelling (1935), Hicks (1946) and Samuelson (1947). The first comprehensive treatment of the subject and proof of the basic duality of cost and production was provided by Shephard (1953). Subsequently, extensions of the formal theory of duality were later made by Uzawa (1962), Shephard (1967) and Diewert (1971). A comprehensive collection of studies on the dual approach written by various arthors was also published in two volumes by Fuss and McFadden (1978).

The major advantages of using the cost function in place of the production function were pointed out by Binswanger (1974). These are stated as: (a) cost functions are homogeneous in prices regardless of the homogeneity properties of production functions; (b) factors of production measured in prices are proper exogenous decision variables; (c) the error term is not as great in using cost figures; (d) biased estimates of production parameters are not affected, especially in the case of logarithmic cost functions; and (e) factor prices are not greatly affected by multicollinearity in estimating cost functions. In addition to these, the pricipal advantage of using a cost function is that cost data are more readily available from farm accounting records.

The production function (3.1) can be alternatively discribed by the cost function, as:

$$C = f(P_K, P_L, P_{L'}, P_D, P_I, P_F, P_O) \qquad (3.2)$$

where

C = total cost per unit of time

$P_K \ldots P_O$ = input prices of capital, labor, contract/custom field work, land, interest on loans, fertilizer, and other divisible inputs.

3.1.2 FUNCTIONAL FORM OF THE TRANSLOG COST MODEL

The analyses of economies of scale and optimum size of independent sugarcane farms on the Hilo Coast employ the translog cost function to formulate the relationships between output and the specified number of inputs. The properties of the translog cost function were developed by Christensen, Jorgerson and Lau (1971). Applications and statistical testing of the translog cost function appeared subsequently in various journals and periodicals by Christensen, Jorgerson and Lau (1973), Berndt and Christensen (1973), Binswanger (1974), Berndt and Wood (1975), Appelbaum (1978), Guilkey and Lovell (1980), Rao and Chotigeat (1981), and Vlastium, Lawrence and Quiggin (1982). Also, a multi-output translog cost function with specialized applications was demonstrated by Ray (1982).

The translog cost function is given by the following logarithmic equation:

$$
\begin{aligned}
\ln C = {} & \ln \alpha_0 + \alpha_Y \ln Y + \alpha_K \ln P_K \\
& + \alpha_L \ln P_L + \alpha_{L'} \ln P_{L'} + \alpha_D \ln P_D \\
& + \alpha_I \ln P_I + \alpha_F \ln P_F + \alpha_O \ln P_O \\
& + 1/2\, \beta_{KK} (\ln P_K)^2 + \beta_{KL} \ln P_K \ln P_L \\
& + \beta_{KL'} \ln P_K \ln P_{L'} + \beta_{KD} \ln P_K \ln P_D \\
& + \beta_{KI} \ln P_K \ln P_I + \beta_{KF} \ln P_K \ln P_F \\
& + \beta_{KO} \ln P_K \ln P_O + 1/2\, \beta_{LL} (\ln P_L)^2 \\
& + \beta_{LL'} \ln P_L \ln P_{L'} + \beta_{LD} \ln P_L \ln P_D \\
& + \beta_{LI} \ln P_L \ln P_I + \beta_{LF} \ln P_L \ln P_F \\
& + \beta_{LO} \ln P_L \ln P_O + 1/2\, \beta_{L'L'} (\ln P_{L'})^2 \\
& + \beta_{L'D} \ln P_{L'} \ln P_D + \beta_{L'I} \ln P_{L'} \ln P_I \\
& + \beta_{L'F} \ln P_{L'} \ln P_F + \beta_{L'O} \ln P_{L'} \ln P_O \\
& + 1/2\, \beta_{DD} (\ln P_D)^2 + \beta_{DI} \ln P_D \ln P_I \\
& + \beta_{DF} \ln P_D \ln P_F + \beta_{DO} \ln P_D \ln P_O \\
& + 1/2\, \beta_{II} (\ln P_I)^2 + \beta_{IF} \ln P_I \ln P_F \\
& + \beta_{IO} \ln P_I \ln P_O + 1/2\, \beta_{FF} (\ln P_F)^2 \\
& + \beta_{FO} \ln P_F \ln P_O + 1/2\, \beta_{OO} (\ln P_O)^2 \\
& + 1/2\, \beta_{YY} (\ln Y)^2 + \beta_{KY} \ln P_K \ln Y \\
& + \beta_{LY} \ln P_L \ln Y + \beta_{L'Y} \ln P_{L'} \ln Y \\
& + \beta_{DY} \ln P_D \ln Y + \beta_{IY} \ln P_I \ln Y \\
& + \beta_{FY} \ln P_F \ln Y + \beta_{OY} \ln P_O \ln Y \qquad (3.3)
\end{aligned}
$$

where

C = total cost per unit of time

Y = output in physical tons of sugarcane

P_K = price of capital

P_L = price of labor

$P_{L'}$ = price of custom/contract field work

P_D = price of land

P_I = price of interest on loans

P_F = price of fertilizer

P_O = price of other variable inputs

The cost function must be homogeneous of degree one in prices in order to correspond to a well behaved production function. This implies the following relationships among parameters:

$$\alpha_K + \alpha_L + \alpha_{L'} + \alpha_D + \alpha_I + \alpha_F + \alpha_O = 1 \qquad (3.4)$$

$$\beta_{KK} + \beta_{KL} + \beta_{KL'} + \beta_{KD} + \beta_{KI} + \beta_{KF} + \beta_{KO} = 0$$

$$\beta_{KL} + \beta_{LL} + \beta_{LL'} + \beta_{LD} + \beta_{LI} + \beta_{LF} + \beta_{LO} = 0$$

$$\beta_{KL'} + \beta_{LL'} + \beta_{L'L'} + \beta_{L'D} + \beta_{L'I} + \beta_{L'F} + \beta_{L'O} = 0$$

$$\beta_{KD} + \beta_{LD} + \beta_{L'D} + \beta_{DD} + \beta_{DI} + \beta_{DF} + \beta_{DO} = 0$$

$$\delta_{KI} + \delta_{LI} + \delta_{L'I} + \delta_{DI} + \delta_{II} + \delta_{IF} + \delta_{IO} = 0$$

$$\delta_{KF} + \delta_{LF} + \delta_{L'F} + \delta_{DF} + \delta_{IF} + \delta_{FF} + \delta_{FO} = 0$$

$$\delta_{KO} + \delta_{LO} + \delta_{L'O} + \delta_{DO} + \delta_{IO} + \delta_{FO} + \delta_{OO} = 0 \qquad (3.5)$$

$$\delta_{KY} + \delta_{LY} + \delta_{L'Y} + \delta_{DY} + \delta_{IY} + \delta_{FY} + \delta_{OY} = 0 \qquad (3.6)$$

Hence, the derived demand functions for the factors of production can be computed by partially differentiating the cost function with respect to factor prices, such as:

$$\partial C / \partial P_i = X_i \qquad (3.7)$$

This result, known as the Shephard's lemma (1967), is expressed in logarithmic form for the translog cost function as:

$$\partial \ln C / \partial \ln P_i = \partial C / \partial P_i \; P_i / C = S_i \qquad (3.8)$$

where S_i indicates the cost share of the ith. factor input. Thus, the translog cost function yields the cost share equations:

$$S_K = P_K/C = \alpha_K + \gamma_{KK} \ln P_K + \gamma_{KL} \ln P_L + \gamma_{KL'} \ln P_{L'} + \gamma_{KD} \ln P_D + \gamma_{KI} \ln P_I + \gamma_{KF} \ln P_F + \gamma_{KO} \ln P_O + \gamma_{KY} \ln Y \quad (3.9)$$

$$S_L = P_L/C = \alpha_L + \gamma_{KL} \ln P_K + \gamma_{LL} \ln P_L + \gamma_{LL'} \ln P_{L'} + \gamma_{LD} \ln P_D + \gamma_{LI} \ln P_I + \gamma_{LF} \ln P_F + \gamma_{LO} \ln P_O + \gamma_{LY} \ln Y \quad (3.10)$$

$$S_{L'} = P_{L'}/C = \alpha_{L'} + \gamma_{KL'} \ln P_K + \gamma_{LL'} \ln P_L + \gamma_{L'L'} \ln P_{L'} + \gamma_{L'D} \ln P_D + \gamma_{L'I} \ln P_I + \gamma_{L'F} \ln P_F + \gamma_{L'O} \ln P_O + \gamma_{L'Y} \ln Y \quad (3.11)$$

$$S_D = P_D/C = \alpha_D + \gamma_{KD} \ln P_K + \gamma_{LD} \ln P_L + \gamma_{L'D} \ln P_{L'} + \gamma_{DD} \ln P_D + \gamma_{DI} \ln P_I + \gamma_{DF} \ln P_F + \gamma_{DO} \ln P_O + \gamma_{DY} \ln Y \quad (3.12)$$

$$S_I = P_I/C = \alpha_I + \gamma_{KI} \ln P_K + \gamma_{LI} \ln P_L + \gamma_{L'I} \ln P_{L'} + \gamma_{DI} \ln P_D + \gamma_{II} \ln P_I + \gamma_{IF} \ln P_F + \gamma_{IO} \ln P_O + \gamma_{IY} \ln Y \quad (3.13)$$

$$S_F = P_F/C = \alpha_F + \gamma_{KF} \ln P_K + \gamma_{LF} \ln P_L + \gamma_{L'F} \ln P_{L'} + \gamma_{DF} \ln P_D + \gamma_{IF} \ln P_I + \gamma_{FF} \ln P_F + \gamma_{FO} \ln P_O + \gamma_{FY} \ln Y \quad (3.14)$$

$$S_O = P_O/C = \alpha_O + \beta_{KO} \ln P_K + \beta_{LO} \ln P_L + \beta_{L'O} \ln P_{L'} + \beta_{DO} \ln P_D + \beta_{IO} \ln P_I + \beta_{FO} \ln P_F + \beta_{OO} \ln P_O + \beta_{OY} \ln Y \qquad (3.15)$$

Uzawa (1962) demonstrated that Allen's partial elasticities of substitution (AES) can be computed from the cost function by the formula:

$$\sigma_{ij} = C\, C_{ij} / C_i\, C_j \qquad (3.16)$$

where

$C_i = \partial C/\partial P_i$

$C_{ij} = \partial^2 C/\partial P_i \partial P_j$ and

$\sigma_{ij} = \sigma_{ji}$

where subscripts on C indicate partial differentiation of the cost function with respect to factor prices. For the translog cost function, the AES cross- price and own-price elasticities are:

$$\sigma_{ij} = (\beta_{ij} + S_i\, S_j) / S_i\, S_j$$

$$\sigma_{ii} = (\beta_{ii} + S_i^2 - S_i) / S_i^2 \qquad (3.17)$$

where $i \neq j$

The AES are not constrained to be constant, but may vary with the cost shares.

The returns to scale (SCE) function associated with the translog approximation is given by:

$$SCE = 1 - (\alpha_Y + \beta_{YY} \ln Y + \beta_{YK} \ln P_K + \beta_{YL} \ln P_L + \beta_{YL'} \ln P_{L'} + \beta_{YD} \ln P_D + \beta_{YI} \ln P_I + \beta_{YF} \ln P_F + \beta_{YO} \ln P_O) \quad (3.18)$$

In summary, the translog cost function is an approximation of the almost homothetical production function, being that the cost function can be written as a separable function in output and factor prices. The translog cost function does not impose restrictions on the elasticities of substitution between units in the production process and economies of scale can easily be derived, as shown above.

3.1.3 ESTIMATION PROCEDURE OF THE TRANSLOG COST MODEL

The estimation procedure used in the translog cost model presented in the previous section entails an econometric approach which quantifies the economic process in terms of relationships. The statistical technique used to explain these relationships is a multivariate regression

system which jointly estimates the translog cost function (3.3) and the cost share equations (3.9-15). Including the cost share equations in the estimation procedure has the beneficial effect of adding many additional degrees of freedom without adding any unrestrictive regression coefficients. This would result in more efficient estimates than would be obtained by only applying ordinary least squares to the cost function.

The multivariate regression system which jointly estimates the translog cost function and the cost share equations is estimated by means of a simultaneous equation system. In this procedure, regression coefficients in all equations are approximated simultaneously be applying Aithen's (1934-35) generalized least-squares to the whole system of equations. Since the technique of the two-stage Aithen estimator does not attempt to account for the possibility that the error terms among equations are correlated, the three-stage least squares technique is used to estimate the model. This technique uses the two-stage least squares as its first two stages, but only to obtain estimates of the covariance and the variances of the error terms in each equation. Then the "stacking" routine of Zellner (1962) is used to estimate all the coefficients and their standard errors in all the simultaneous equations at once. By so doing, the correlation of error terms among equations is taken into consideration.

A problem arises in specifying additive disturbances for each of the share equations and for the cost function. According to Christensen and Greene (1976), the cost share equations do not contain the disturbance term from the cost function since they are derived from the cost function through differentiation. This is contrary to the assumption that the disturbances have a joint normal distribution allowing for nonzero correlations for a particular firm but imposing zero correlations across firms. In order to make the Zellner procedure operational, it is necessary to delete one of the share equations from the system. The estimates so obtained, however, are not invariant to the equation that is deleted, as shown by Barten (1969). Invariance can be obtained by iterating the three-stage least square procedure until the estimated coefficients and residual covariance matrix converge. It is for this reason that the three-stage least squares estimator is employed in this study.

3.1.4 ASSUMPTIONS OF THE TRANSLOG COST MODEL

The following assumptions apply to the translog cost function estimated by means of the three-stage least squares model as discussed above:

1. At the level of an individual firm, it may be assumed that the supply of inputs is perfectly elastic, and therefore input prices can be taken as fixed.

2. At the firm or industry level, input prices are proper exogenous variables. Entrepreneurs make decisions on factor use according to exogenous prices, which makes actual factor quantity levels endogenous decision variables.

3. The regressors in the cost share equations (3.9-15) are uncorrelated with the disturbance terms.

4. The derivation of the cost share equations from logarithmic derivatives of the translog function is the result of random errors in cost minimizing behavior. For this reason, an additive disturbance term is considered in each of the share equations.

5. The cost shares of each equation (3.9-15) always sum to unity; hence, the sum of the disturbances across the equations is zero at each observation. This assumption implies that the disturbance covariance matrix is singular and non diagonal. By dropping the disburbance term from one of the equations in the system results in the disturbance column vector being independently and identically distributed with mean vector zero and nonsingular covariance matrix.

3.2 MODIFIED COBB-DOUGLAS PRODUCTION FUNCTION

3.2.1 STRUCTURAL FORM OF THE CONVENTIONAL COBB-DOUGLAS MODEL

In order to understand the modified Cobb-Douglas model, it is necessary to define the structural form of the conventional Cobb-Douglas production function which is expressed by the following relationship:

$$Y = f(D, L, C) \qquad (3.19)$$

where

Y = output per unit of time

D = land

L = labor

K = capital

Output (Y) is measured in actual units of output measured in sugarcane tons; and inputs (D,L,K) are expressed in units of inputs measured in acres of land, hours of labor and cost of capital.

3.2.2 FUNCTIONAL FORM OF THE MODIFIED COBB-DOUGLAS MODEL

The functional form of the Cobb-Douglas production model is described by the following algebraic relationship:

$$Q = AD^{a} \; L^{b} \; K^{c} \qquad (3.20)$$

where A is a positive constant and the exponentials a, b and c are positive fractions. Several major features of this function are: 1) it is homogeneous of degree (a + b + c); 2) in the special case of a + b + c = 1, it is linearly homogeneous; and 3) its isoquants are negatively sloped throughout and convex downward. In the case a + b + c = 1, there are constant returns to scale, because the function is linearly homogeneous, which means that raising all inputs (independent variables) k-fold will always raise the output (value of the function) exactly k-fold, also.

Special economic meaning is assigned to the exponents a, b and c in the linearly homogeneous Cobb-Douglas production function. The relative shares of each input attributed to output is contained in each of the parameters which should be positive numbers.

The Cobb-Douglas production function expressed in (3.20) can also be transposed into the natural log of both sides, as follows:

$$\ln Q = \ln A + a \ln D + b \ln L + c \ln K \qquad (3.21)$$

where the dependent and independent variables are the same as in (3.19) and (3.20).

The Cobb-Douglas production function can also estimate variable elasticities and returns to scale by introducting an index variable into the equation which represents an intensity factor of production. In the case of the modified Cobb-Douglas production function, the index variable is defined as capital services measured in dollars per acre of land. Capital services refers to the non-fixed costs related to fertilizer, herbicides, seeds and other related factors of production.

The capital intensity variable (I)is hypothesized to influence the partial elasticities as well as scale returns, and is expressed as follows:

$$Y = A\ D_1^{\,a(I)}\ L_2^{\,b(I)}\ K_3^{\,c(I)} \qquad (3.22)$$

where

X_1 = land

X_2 = labor

X_3 = capital

If I is believed to influence one or more of the partial production elasticities, (3.22) can be written in logarithmic form as follows:

$$\ln Y = \ln A\ \ln D_1^{\,a(I)}\ \ln L_2^{\,b(I)}\ \ln K_3^{\,c(I)} \qquad (3.23)$$

3.2.3 ESTIMATION PROCEDURE OF THE MODIFIED COBB-DOUGLAS PRODUCTION MODEL

The equation expressed in (3.23) is linear in the parameters provided that (a + b + c) is linear in its parameters, and therefore can be estimated by the direct application of the multivariate least squares econometric equation. The difference between the conventional and the modified Cobb-Douglas production function is the presence of several interaction terms in the latter equation which are the product of the index variable and the transformed X variables.

The modified production function with variable production elasticities represents an infinite number of independent coefficients. At each level of the index variable, there is a unique set of partial elasticities for each combination of inputs and given scale returns.

3.2.4 ASSUMPTIONS OF THE MODIFIED COBB-DOUGLAS PRODUCTION MODEL

The assumptions of the modified Cobb-Douglas production function estimated by means of a multivariate least squares econometric equation are as follows:

1. While the conventional Cobb-Douglas production function assumes that input-output relationships can be described satisfactorily by constant elasticities of production, the modified Cobb-Douglas production function

permits variable elasticities and scale returns providing more flexibility for analysis.

2. The modified Cobb-Douglas production function assumes that the intensity index variable influences the partial production elasticities of one or more of its inputs.

3. The estimated parameter(s) for each of the input variables indicate(s) its share or contribution to production.

4. The sum of the partial production elasticities provides estimates of scale returns which vary over the range of observations.

3.3 QUADRATIC FUNCTION

3.3.1 STRUCTURAL FORM OF THE QUADRATIC MODEL

The relationship which describes the structural form of the quadratic model is specified as:

$$AVECOST = f(Y) \qquad (3.24)$$

where

AVECOST = Average cost per ton of sugarcane

Y = output of sugarcane measured in tons

Average cost per ton of sugarcane is determined by the ratio of total cost of production to output measured in tons.

3.3.2 FUNCTIONAL FORM OF THE QUADRATIC MODEL

The reason for choosing the quadratic model is to determine the minimum cost at which independent growers on the Hilo Coast can operate their sugarcane farms. The functional form of the model is a second-degree polynomial equation which takes on the typical U-shape characteristic in average cost analysis.

The quadratic function is described by the following relationship:

$$AVECOST = \alpha + \beta Y_1 + \beta Y_2^{\,2} \qquad (3.25)$$

where

α = intercept term

X_1 = output in sugarcane tons

$X_2^{\,2}$ = output in sugarcane tons squared

The unique feature of the quadratic function is that it can estimate minimum average cost at a specific level of production. This is performed mathematically by differentiating the estimated quadratic function, setting these values at zero and solving the remainder of the equation.

3.3.3 ESTIMATION PROCEDURE OF THE QUADRATIC MODEL

The quadratic function, being a second-degree polynomial, is estimated by means of a regression equation in a square root transformation. The signs of the parameters indicate whether minimum cost values are present. Cost values are present if the non-squared parameter is negative and the squared parameter is positive. First order differentiation of the equation is necessary to estimate minimum average cost.

3.3.4 ASSUMPTIONS OF THE QUADRATIC MODEL

The following assumptions apply to the quadratic model:

1. Average costs follow the form of the U-shaped curve which is typical of the quadratic function, thereby providing information on economies and diseconomies of scale.

2. Minimum average cost is easily estimated by the quadratic function.

3. The first derivative of the quadratic function provides an estimate of the optimum output level of production

3.4 COMPARISON OF ECONOMETRIC MODELS

Each of the three econometric models chosen for estimating economies of scale and optimum farm size provide different kinds of information relating to the objectives of the study. The translog function estimates total costs as a function of output and input prices; whereas the quadratic function is limited in scope by explaining average costs as a function of one variable, output. The modified Cobb-Douglas function examines the effects of a capital intensity variable on physical output measured in tons of sugarcane as a function of land, labor and capital.

Of the three functions, the translog function is more flexible in that it can explain economies of scale in terms of total costs as a functional relationship of output and input prices. This also includes the substitution effects between output and prices, as well as between various input prices. These are proper exogenous variables that enhance the decision making process. The unique feature of the translog function is that it can estimate economies of scale directly from the function itself, which includes own and cross output/price and price/price substitution effects. However, because of the restrictions imposed on the translog cost function, statistical testing is less reliable than for other functional forms.

The quadratic function provides estimates of economies of scale, minimum cost, optimum level of output and farm

size. However, the function is limited in that it only includes two variables in the equation, that of average cost and output measured in tons of sugarcane. It does not include price substitution effects. Although the function is less responsive to cross sectional analysis, it can be statistically tested both by the standard F and t probability values.

The modified Cobb-Douglas function estimates economies of scale by means of including a capital intensity variable in the equation. The responsiveness of the intensity variable can affect each of the independent variables in the equation. This is done by progressively increasing the intensity variable and measuring the partial production elasticities of land, labor and capital. The total production elasticity of output in relation to these input variables is a measure of economies or diseconomies of scale. The model is adaptable to cross sectional data and can be statistically tested.

3.5 STATISTICAL TESTS OF SIGNIFICANCE

Based on the assumptions regarding the stochastic framework of the econometric models discussed in the previous sections, the following statistical tests are to be used for each estimated equations:

1. Significance tests of the sample regression coefficients. Assuming that the errors are normally

distributed with a mean of zero and variance ^{2}, the value of the Durbin-Watson ("t" statistic) to test whether the sample regression coefficients $_i$ are significally different from zero at the same probability level is given by:

$$t = \beta_i / \sqrt{\text{variance } (\beta_i)} \qquad (3.26)$$

where variance $= \sum (C_i - C_i)^2 / n-k-1$

If t is larger than the tabled level of t with (n-k-1) degrees of freedom, then β_i is significantly different from zero at the level of probability.

2. Coefficient of multiple determination. The correlation between the n observed values of Y and corresponding Y is shown by the coefficient of multiple correlation, denoted by R. The coefficient of multiple determination, R^2, indicates the percentage of the variation in the n observed Y values that is explained by the regression equation. This is a measure of the goodness of fit of the estimated regression equation, shown as:

$$R^2 = \sum \beta_i \sum P_{ij} C_j / \sum C_j^2 \qquad (3.27)$$

The adjusted coefficient of multiple determination, $\bar{R}^2$, is used if it is determined that the number of parameters in the production function estimation is large, or the number of sets of observations is small. It is calculated as:

$$\bar{R}^2 = 1 - (1-R^2)\ (n-1/n-k) \qquad (3.28)$$

3. Analysis of variance for multiple regression. An overall test of the significance of the regression function is made by estimating the value of the "F" statistic, given by:

F = Regression mean square / Error mean square (3.29)

where F has k and (n-k-1) degrees of freedom as shown in the analysis of variance table for multiple regression by Ezekiel (1959). The F statistic provides a test of the null hypothesis that $\beta_1 = \beta_2 = \ldots = \beta_k = 0$. If F from 3.26 is larger than the tabled value of F at the desirable probability level, the null hypothesis would be rejected.

3.6 DATA SOURCE AND CONSTRUCTION

The data required for the three stage least squares estimation of the translog cost function and share equations, the modified Cobb-Douglas production function, and the quadratic function for the independent sugarcane growers on the Hilo Coast include total cost, output and resource prices depending on the formulation of the model. This information was obtained from two separate farm surveys that were taken during 1977 and 1980 as a joint effort between the College of Tropical Agriculture and Human Resources of the University of Hawaii and the Hawaii

Agricultural Reporting Service.

The 1977 data consisted of a random stratified sample of 66 sugarcane farms representing 312 independent growers of the United Sugarcane Growers Cooperative. All of these farmers marketed their cane through the Hilo Coast Processing Company. Even though the study was limited to this Cooperative, the implications derived from the research may be extended to other independent growers throughout the Hilo Coast on the Island of Hawaii.

The 1980 survey included 37 usable questionnaires of independent sugarcane growers. The samples were selected on a probability-proportional-to-size basis from a population size of 318 sugarcane farmers. Of the 37 growers, 25 processed their sugarcane at the Hilo Coast Processing Company, ten at the Davies Hamakua Sugar Company and two at the Ka'u Sugar Company. The results of the research were extended to all of the independent farmers growing sugarcane at the commencement of the study.

The data collected in the surveys included information on farm size measured in acres, sugarcane in tons and various input costs of the farm operation. Prices paid by sugarcane growers for factors of production were not included in the survey. In order to estimate the translog cost function and share equations, data on input prices were utilized from the U.S. Agricultural Input Price Index for both production periods.

The total outlay of costs made by the independent sugarcane growers along the Hilo Coast is shown in Table 3.1. The cost categories for the major inputs, as mentioned earlier, are separated into eight items, namely: 1) capital; 2) labor; 3) custom/contract field work; 4) land; 5) interest on loans; 6) fertilizer; 7) management; and, 8) other variable inputs. It should be noted that the eight factors of production result in a total combination of all variable costs used in producing sugarcane. In order to provide a better understanding of these costs, a discussion on each of the inputs is presented below. The cost categories cover operational costs only.

1. Equipment operating costs. This includes operating costs for machinery, fuel and lubrication as well as repairs required for continuous operation. Such items often cover parts, labor, tires, tubes, small tools and the farm use of a personal car. Machinery owership costs also include taxes, licenses and insurance paid by the sugarcane growers.

2. Labor. This cost item includes operator and family labor as well as hired labor. The labor required to grow sugarcane begins with cutting the cane into seed pieces, preparing the land, planting the seed cane, applying fertilizer, chemical weed control, and harvesting of the crop. The period from plant or ratoon crop to harvesting covers a period of 20 to 26 months, with an average of 23

TABLE 3.1

Sugarcane Production Costs per Acre, Independent Cane Growers, Island of Hawaii

1977 (66 farmers)[a] and 1980 (37 farmers)[b] Crop Year

Crop Item	1977 Crop Year Amount $ per Acre	1977 Crop Year Percent of total	1980 Crop Year Amount $ per Acre	1980 Crop Year Percent of Total
Equipment	131.40	12.94	240.81	16.92
Labor	113.50	11.18	139.56	9.80
Custom field work	108.92	10.73	265.49	18.65
Land	67.87	6.68	73.77	5.18
Interest on loans	102.38	10.08	186.86	13.13
Fertiliser	316.66	31.19	262.68	18.45
Overhead	66.42	6.54	152.20	10.69
Variable inputs	108.16	10.65	102.14	7.17
Total	1,015.31	99.99	1,423.51	99.99

Sources a and b: Holderness, Vieth, Scott, and Briones (1979,1982).

months.

3. Custom/contract field work. The labor required by this cost category includes land preparation and planting as well as custom application of herbecides and fertilizer. Medium sized sugarcane farms require more custom/contract field work than small farms, since the latter usually use family labor, while larger farms are less dependent on this source of labor and depend more on machinery.

4. Land. Land costs include rent for sugarcane growers who lease their land, and a land charge for growers who own their own farms. For owned land, a land charge is imputed by multiplying the FLB (Federal Land Bank) rate at 6.0 percent per annum at the time of the survey by the acquisition cost of the land plus the real property tax. Such taxes are also usually paid by sugarcane growers who lease their land. Included in this category are costs incurred by growers for purchasing other growers' leases to expand sugarcane acreage. It does not include mortgage payments for fee purchases.

5. Interest on loans. Loans are made for planting/replanting, seed, fertilizer, herbicide and labor. Interest paid on capital for machinery and buildings is included under costs for general farm overhead. Banks, credit unions and other financial institutions provide these loans using the sugar crop as the lender's collateral. Since loans are typically substantial, interest on these

advances make up a considerable part of the cost of growing sugarcane. Interest payments are based on the PCA (Production Credit Association) average rate, which was 10.8 percent per annum at the time of the survey, multiplied by production inputs over time. This category does not include payments paid on principal.

6. Fertilizer. Fertilizer costs also include the cost of purchasing crushed coral. Fertilizer is usually applied by machine at planting time followed by one or two additional applications until the cane grows too densely for the machine to operate. Thereafter, it is necessary to fertilize at least two more times by air. Fertilizer is one of the most costly production inputs.

7. Overhead. Overhead costs include management and general farm overhead, covering property insurance, financial and legal fees, workmen's compensation insurance, temporary disability insurance, social security, depreciation, and interest on machinery and buildings at 5.5 percent per annum (11 percent / 2).

8. Other variable inputs. These include mostly the costs of seedcane and herbicides as well as other chemicals. Costs for these items are grouped together since they were less significant than the costs of other factors of production listed above.

CHAPTER IV

EMPIRICAL RESULTS

The original intent of this study was to utilize a multivariate regression model which would jointly estimate the transcendental cost function and selected cost share equations by means of a simultaneous equation system. This prodecure would provide information on scale economies, elasticities of factor demand and substitution effects of resource prices applied to the production process. Considerable time and effort were spent in developing the translog cost function and respective share equations. It became necessary, however, to select an alternative to this approach because of the lack of adequate price variation in the independent variables within the system of equations. Although the problem of of not having a positive non-singular matrix, being that the matrix could not be inverted and thus post-multiplication could not be attained, was overcome by applying price variations in the regression model, it neither improved statistical precision nor provided meaningful results.

In the final analysis, determinations of economies of scale and optimum size of independent sugarcane farms on the Hilo Coast were based on the following three econometric methods:1) the transcendental logarithmic cost function; 2)

the modified Cobb-Douglas function with variable production elasticities; and 3) the quadratic function. In deriving the econometric equations for each of these functions, the computerized statistical package " SHAZAM " is used for this purpose. The empirical findings for each of these models are presented and interpreted in this chapter.

In addition to the econometric equations which estimate average shapes and forms of varicus functions, a fourth type of analysis is included. This approach, known as the locus of lowest cost points, approximates the economies of scale curve from a scatter of cost and output points. This is accomplished by fitting an envelope curve to the bottom, rather than to the average, of the scatter. Since this method identifies efficiently organized and well operated sugarcane growers, a representative number of these operations is identified and chosen for analysis. As a result, inferences on the optimum farm size are made by means of this approach.

4.1 TRANSCENDENTAL LOGARITHMIC COST FUNCTION

4.1.1 PARAMETER ESTIMATES AND STATISTICAL TESTS

The unique feature of the transcendental logarithmic cost function, also known as the translog cost function (3.3), is that it allows scale economies to vary with each level of output. The purpose of this section is to estimate the translog cost function thereby deriving the necessary

parameters for determining economies or diseconomies of scale. Alternative restrictions are imposed on the model to investigate their impact on the shape of the estimated cost curves. Because of these restrictions, statistical tests of significance, such as the F test and t test values, are less reliable than for functional forms derived from other econometric models.

Economies of scale are usually defined as the relative increase in output resulting from a proportional increase in all inputs as farm operation expands. However, it is also appropriate to represent scale economies by the relationship between total cost and output. In this sense, elasticities of substitution are expressed as the incremental change in total cost resulting from a given increase in output. This is referred to as the elasticity of total cost with respect to output. Scale economies (SCE) can, therefore, be defined as unity minus elasticity of total cost with respect to output:

$$SCE = 1 - \partial \ln C / \partial \ln Y \qquad (4.1)$$

The results of this equation indicate positive numbers for positive scale economies and negative numbers for scale diseconomies.

The elasticity of total cost with respect to output ($\partial \ln C / \partial \ln Y$) can be directly derived from the translog cost function of the econometric equation, expressed as:

$$\alpha_Y + \gamma_{YY} \ln Y + \sum_{i} \gamma_{Yi} P_i \qquad (4.2)$$

One of the important properties of the translog cost function is that it does not constrain the structure of production to be homothetic. In duality theory, a cost function represents a homothetic production structure only if the cost function is expressed in output. The implication here is that the factor ratio remains constant whenever its price ratio is constant. In the scale elasticity equation (4.2), homotheticity is incurred if $\gamma_{Yi} = 0$.

A homothetic production structure can also be homogeneous only if the elasticity of cost with respect to output is constant. Scale elasticity (4.2) is constant if the term $\gamma_{Yi} = 0$ and $\gamma_{YY} = 0$. Furthermore, the elasticities of price substitution directly expressed in the translog cost function can be restricted to unity if $\gamma_{ij} = 0$.

Table 4.1 identifies six different models for estimating economies of scale under the following assumptions: Model A estimates scale economies directly from the translog cost function that imposes neither homothetic, homogeneous or unitary elasticity restrictions; Model B imposes homotheticity; and, Model C imposes homogeneity. Models D, E and F, correspond to Models A, B and C, respectively, with the added restriction of unitary elasticities of substitution.

TABLE 4.1

Econometric Equations for Estimating Scale Economies of Independent Sugarcane Growers on the Hilo Coast

Translog SCE Model A:	$1 - (\alpha_Y + \beta_{YY} \ln Y + \sum_{i=1}^{n} \beta_{Yi} \ln P_i)$
Homotheticity SCE Model B:	$1 - (\alpha_Y + \beta_{YY} \ln Y)$
Homogeneity SCE Model C:	$1 - \alpha_Y$
Unitary Elasticity of Substitution SCE Model D:	$1 - (\alpha_Y + \beta_{YY} \ln Y + \sum_{i=1}^{n} \beta_{Yi} P_i)$
Homotheticity Unitary Elasticity of Substitution SCE Model E:	$1 - (\alpha_Y + \beta_{YY} \ln Y)$
Homogeneity Unitary Elasticity of Substitution SCE Model F:	$1 - \alpha_Y$

TABLE 4.2

Regression Coefficients for Estimating Economies of Scale for Models A-F with Standard Errors in Parentheses

$X/^a$	Model A	Model B	Model C	Model D	Model E	Model F
α_Y	0.8557 (0.5455)	0.2944 (0.3519)	0.9277*** (0.0376)	0.8182* (0.4548)	0.2632 (0.3647)	0.9447 (0.0379)
β_{YY}	0.0575 (0.0464)	0.0780* (0.0431)		0.0651 (0.0449)	0.0840 (0.0447)	
β_{YK}	2.0623 (1.7087)			2.3206* (1.2515)		
β_{YL}	0.4108 (0.9808)			-0.0128 (0.8278)		
β_{YC}	-2.2593* (1.3671)			-1.8054 (1.1592)		
β_{YO}	-0.2138 (0.6341)			-0.5024 (0.4576)		
R^2	0.9206	0.9174	0.9137	0.9112	0.9066	0.9021

a Estimated Coefficients are: Y=output; K=capital; L=labor; C=custom field work; and O=other divisible inputs.
*** Significant at the one percent probability level.
* Significant at the ten percent probability level.

The estimated regression coefficients of the translog cost function specified in Table 4.1 for the various models are shown in Table 4.2. The dependent variable for the translog cost function is the total cost incurred by independent sugarcane growers on the Hilo Coast. The independent variables include the prices for varying and fixed capital (P_K), family and hired labor (P_L), custom field work (P_C) and other inputs (P_O) which include fertilizer, herbicide and seed. Sugarcane (Y) measured in tons is also treated as an independent variable.

The choice of using tons of sugarcane rather than raw sugar as a measurement of output stems from the assumption that independent sugarcane growers base their managerial decisions on per acre yields of sugarcane and input prices and not on the per acre yield of raw sugar and processing and marketing costs. However, per acre yield of raw sugar would better reflect the effects of yield of raw sugar per ton of sugarcane on economies of scale.

In reviewing the parameters in Table 4.2, it is necessary to examine the level of t-ratio values which measure whether a particular parameter is statistically different from zero. Although the number of values significant at an acceptable level of probability is low, this is usually expected since statistical testing with the translog cost function is less relaiable than for other functional forms.

The F statistic which is used to test the reliability of the combined effect of the estimated coefficients in the regression equation was not provided for the six models of the translog cost function. In such a case, it is necessary to examine the t-ratio values or standard error terms of each coefficient separately for determining statistical reliability.

Another statistical test which is commonly used in econometrics is the coefficient of determination, commonly known as 'R-squared'. The R^2 is a descriptive statistic that indicates whether the estimated regression line is either a 'good' or 'poor' fit. The ordinary least squares (OLS) regression equation in this analysis has a very high R^2 of 0.9206. The high R^2 in the estimated translog cost function is most probably due to the small variation across each unit of observation.

Estimates of scale economies can be derived for the independent sugarcane growers on the Hilo Coast by evaluating the models in Table 4.2 at observable levels of output and factor prices. In order to analyze scale economies, sugarcane growers were separated into five size groups by farm acres. Each model presented in Table 4.2 is estimated with median output and factor prices imputed in each group. The farms were divided into these particular size groups to provide an adequate number of observations in each group. Size groups are classified into 1.0-9.9 acres

with median output at 649.76 tons; 10-24.9 acres at 1,512.47 tons; 25-49.9 acres at 2,877.85 tons; 50-99.9 acres at 5,611.65 tons; and 100+ acres at 15,506 tons.

In deriving scale economies, elasticities of total cost with respect to output are estimated as shown in Table 4.3. The estimated elasticities indicate a percentage change in total cost resulting from a one percent change in output. Scale economies as shown in Table 4.4 indicate the percentage of cost savings or loss as related to the size of the farm operation.

4.1.2 INTERPRETATION AND ANALYSIS

Tables 4.3 and 4.4 present both the estimated elasticities of substitution of total cost with respect to output and scale economies of the independent sugarcane growers for the six models presented in the previous section. In order to further facilitate the analysis, the various models are separated into five size groups by acres.

Estimates of the homogeneous models, C and F, are constant at all levels of farm size and output, as expected. Model F is a special case of the Cobb-Douglas function being restricted by both homogeneity and unitary elasticity of substitution conditions. Model C is only limited by the restriction imposed by homogeneity. The results of these two models as presented in Table 4.3 indicate constant elasticities of 0.9277 for Model C and

TABLE 4.3

Estimated Elasticities of Total Cost with Respect to Output for Various Size Groups in Acres for Independent Sugarcane Growers on the Hilo Coast

Models	1.0-9.9 acres	10-24.9 acres	25-49.9 acres	50-99.9 acres	100+ acres
Non-Homothetic					
A	0.8278	0.9276	0.9750	1.0365	1.0884
D	0.8001	0.9331	0.9801	1.0516	1.1175
Homothetic					
B	0.7996	0.8655	0.9157	0.9677	1.0469
E	0.8032	0.8782	0.9322	0.9883	1.0700
Homogeneous					
C	0.9277	0.9277	0.9277	0.9277	0.9277
F*	0.9447	0.9447	0.9447	0.9447	0.9447

* Model F is a special case of the Cobb-Douglas function.

TABLE 4.4

Estimated Scale Economies for Various Size Groups in Acres for Independent Sugarcane Growers on the Hilo Coast

Models	1.0-9.9 acres	10-24.9 acres	25-49.9 acres	50-99.9 acres	100+ acres
Non-Homothetic					
A	0.1722	0.0725	0.0250	-0.0354	-0.0884
D	0.1999	0.0669	0.0199	-0.0516	-0.1175
Homothetic					
B	0.2004	0.1345	0.0843	0.0323	-0.0469
E	0.1928	0.1218	0.0678	0.0117	-0.0700
Homogeneous					
C	0.0723	0.0723	0.0723	0.0723	0.0723
F*	0.0553	0.0553	0.0553	0.0553	0.0553

* Model F is a special case of the Cobb-Douglas function.

0.9447 for Model F. Thus, if output is increased by one percent at any level of production, total cost would increase by 0.9277 and 0.9447 percent for Models C and F, respectively. As noted in Table 4.4, the estimated scale economies are 0.0723 and 0.0553 for models C and F, respectively, indicating cost savings for all size groups. Since the models are restricted by constant elasticity of cost and do not change with respect to output and the Cobb-Douglas function does not take into account price substitution effects, an accurate interpretation for all size groups is limited. Elasticities and scale economies reflect, at most, average estimates across all levels of output.

By including the output variable into the scale elasticity equation and restricting the price ratios to be constant, as in models B and E, estimated elasticities of total cost with respect to output vary at increasing rates as shown in Table 4.3. Positive scale economies occur for farms up to 99.9 acres in size and decrease at 100+ acres as indicated in Table 4.4. Under both restrictions of homotheticity and unitary elasticity of substitution, the findings indicate that proportionately greater cost savings occur within the 1.0-9.9 acre size group and decrease at a positive rate up to the 99.9 acre level. Highest marginal returns to scale are indicated for small sugarcane growers. This may be attributed to cost savings in equipment due to

the high usage of family labor for small farms as compared to larger farms.

The estimates of model A and D, the unrestrictive model and the unitary elasticity of substitution case approximate each other in their parameters. By eliminating the effects of homotheticity and homogeneity, it appears that economies of scale occur up to 49.9 acres and diseconomies occur for farms of 50 acres and larger. The conditions of varying or unitary elasticity of substitution do not greatly affect the estimated elasticities of total cost with respect to output or scale economies at different levels of production. It appears that with the less restrictive models, marginal cost savings are greater at lower levels of output. Since family labor may explain the higher level of incremental cost savings for smaller farm operations, other factors aside from those included in these models should be considered.

The relationship between scale economies and various size groups measured in acres as depicted by the translog cost function in Model A of Table 4.4 can be further explained by an example. If per acre output for sugarcane farms between 1.0 and 9.9 acres is increased by one percent, total cost increases 0.83 percent. Thus, average cost savings of 17 percent are gained through economies of scale.

Similarly, for farms in the 10-24.9 acre size group, a one percent increase in output generates a 0.93 percent

increase in total cost, with cost savings of 7 percent. For the 25-49.9 acre size group, a one percent increase in output generates a 0.98 percent increase in total cost, reflecting average savings of 2 percent as farm size is increases.

For the two largest size groups, on the other hand, economies of scale are negative. As size of farm increases, a one percent increase in output results in an increase in the total cost of 1.04 percent for the 50-99.9 acre size group and 1.09 percent for the size group of 100 acres or more, thus increasing cost by 4 percent and 9 percent, respectively.

The research findings thus indicate a potential for increasing net returns per unit through expansion in farm size for the smaller size groups, but a potential for decreasing returns per unit for the two larger size groups. Further research is needed to explain the reasons for diseconomies of scale for the two larger size groups.

4.2 MODIFIED COBB-DOUGLAS FUNCTION WITH VARIABLE PRODUCTION ELASTICITIES

LIST 4.2.1 PARAMETER ESTIMATES AND STATISTICAL TESTS

By including an index variable representing an intensity factor of production into the Cobb-Douglas function, variable elasticities and returns to scale can be estimated for independent sugarcane growers on the Hilo

Coast. It is therefore hypothesized that capital intensity of production influences partial elasticities and returns to scale. This index variable is defined as capital services measured in dollars per acre of land. Capital services refers to the flow of services related to fertilizer, herbicides, seedcane and other variable factors of production as well as capital services related to machinery. The dependent variable of the modified function is harvested sugarcane measured in tons. The independent variables are land, labor and capital services defined as land in acres, labor as family and hired labor in hours, and capital services measured in dollars.

The results of the Cobb-Douglas production function and the capital intensity index for varying production are shown below:

$$Y = 4.608\ D_1^{0.9494}\ L_2^{0.0231+.000001902\ I^2}$$

$$K_3^{-0.003165-0.000001305\ I^2} \qquad (4.3)$$

where

Y = sugarcane in tons

D_1 = land in acres

L_2 = labor in hours

K_3 = capital in dollars

I^2 = index measure

TABLE 4.5

Estimates Coefficients of the Modified Cobb-Douglas Production Function with Standard Errors

Variables [a]	Parameters	Standard Errors
Constant	4.6081	(0.0991)***
δ_1	0.9494	(0.0268)***
δ_2	0.0231	(0.0166)
λ_2	0.1902-05	(0.1341-05)
δ_3	-0.003165	(0.01479)
λ_3	-0.1305-05	(0.7885-06)*
	R^2=0.9802	F=602.334

a δ_1=land; δ_2=labor; δ_3=capital; λ_2=labor index; λ_3=capital index.

*** Significant at the one percent probability level.
* Significant at the ten percent probability level.

Table 4.5 shows the estimated coefficients with their standard errors and levels of statistical significance. The parameters in the equations suggest that partial elasticities and returns to scale are influenced by capital intensity of production. As capital intensity increases, the results indicate a positive effect on land and labor but a negative effect on capital.

Partial production elasticities and scale returns are shown in Table 4.6 for alternative levels of the index variable. The index variable refers to capital intensity in dollars per acre of sugarcane land which represents the actual range of the samples in the survey from one dollar to 700 dollars. Only the labor and capital variables are adjusted by the index variable. The high correlation between land and the index variable prevented the estimation of the interaction between land and the capital/land ratio. Beta 1, beta 2 and beta 3 refer to the partial elasticities for land, labor and capital, respectively. The sum of the partial elasticities results in the scale returns identified by the phi parameter. Economies and diseconomies of scale are noted as to whether phi is greater or lesser than 1.0 as I expands.

In order to compare the results of the modified Cobb-Douglas function with the conventional Cobb-Douglas production function, the latter function was estimated using the same set of samples as the former function having the results:

TABLE 4.6

Partial Production Elasticities and Scale Returns for the Modified Cobb-Douglas Production Function by Index of Production Technique

Index of Production Technique[a]	Partial Production Elasticities Beta 1 Land	Beta 2 Labor	Beta 3 Capital	Scale Returns Phi
1	0.9494	0.02310	-0.00317	0.96933
2	0.9494	0.02311	-0.00317	0.96934
4	0.9494	0.02313	-0.00318	0.96935
6	0.9494	0.02317	-0.00321	0.96836
8	0.9494	0.02322	-0.00325	0.96937
10	0.9494	0.02329	-0.00329	0.96940
12	0.9494	0.02337	-0.00335	0.96942
25	0.9494	0.02429	-0.00398	0.96971
50	0.9494	0.02786	-0.00643	0.96083
100	0.9494	0.04002	-0.01621	0.97321
200	0.9494	0.09918	-0.05536	0.99322
300	0.9494	0.19428	-0.12061	1.02307
400	0.9494	0.32740	-0.21196	1.06484
500	0.9494	0.49860	-0.32941	1.11859
600	0.9494	0.70782	-0.47296	1.18426
700	0.9494	0.95508	-0.64261	1.26187

a Index of capital intensity of production measured in capital services in dollars per acre of land.

$$Y = 4.566\ D_1^{0.9515}\ \ L_2^{0.0355}\ \ K_3^{-0.0076} \qquad (4.4)$$

Table 4.7 shows the estimated coefficients with their standard errors and indicators of statistical significance for the conventional Cobb-Douglas function. The sum of the elasticities indicates that slight diseconomies of scale exist at 0.9774. However, scale returns in Table 4.6 for the modified Cobb-Douglas function vary from 0.9693 to 1.2619 indicating both diseconomies and economies of scale, depending on farm size.

4.2.2 INTERPRETATION AND ANALYSIS

Several inferences can be drawn from Table 4.6. The partial production elasticity of labor increases as the capital intensity index becomes larger. On the other hand, the partial production elasticity of capital flow has a negative and inverse effect on the production of sugarcane. The overall effect, however, is that as the capital-intensity variable increases, total physical output increases at an increasing rate. If the cost of capital increases by one percent, output increases by 0.97 percent at the lowest level of the intensity index and increases by 1.26 percent at the highest level.

The results indicate that the partial production elasticity of labor is directly related to the capital intensity of the production technique because its marginal

TABLE 4.7

Estimated Coefficients of Conventional Cobb-Douglas Production Function with Standard Errors

Variables [a]	Parameters	Standard Errors
Constant	4.5660	(0.0989)***
δ_1	0.9515	(0.0211)***
δ_2	0.0335	(0.0130)**
δ_3	-0.0076	(0.0470)
	R^2 = 0.9799	F = 858.483

a δ_1=land; δ_2=labor; δ_3=capital.

*** Significant at the one percent probability level.
** Significant at the five percent probability level.

productivity is higher for more capital-intensive techniques. Likewise, the marginal productivity of capital increases as more capital-intensive techniques are used, resulting in higher negative partial production elasticities for capital. Also, price substitution effects are not taken into account in the Cobb-Douglas production function analysis.

Table 4.6 shows the scale economies for different values of the index variable. Economies of scale take place at an index level of 300 and larger. Growers who adopt more capital-intensive techniques at higher levels of production appear to achieve economies of scale. However, the analysis is limted in that it does not include other factors that may restrict the effect of scale economies. It should also be noted that the marginal rate of scale elasticity does not vary greatly over the entire range of the intensity index.

In comparing the conventional Cobb-Douglas function in Table 4.7 with the modified Cobb-Douglas function in Table 4.5, the scale returns derived from the conventional equation appear to be a weighted average of the scale return in the latter equation. Since most of the sugarcane farms on the Hilo Coast fall into categories of lower capital intensity indexes, it may be concluded that the average scale returns derived from the conventional Cobb-Douglas function is weighted toward smaller farms. Scale returns, therefore, are overstated for farms with less

capital-intensive techniques and understated for farms with more capital-intensive production. The modified Cobb-Douglas variable method, on the other hand, allows for a more comprehensive approach to an analysis of economies of scale than the conventional Cobb-Douglas production method.

4.3 QUADRATIC FUNCTION

4.3.1 PARAMETER ESTIMATES AND STATISTICAL TESTS

Minimum cost and optimum level of farm operations for independent sugarcane growers on the Hilo Coast are approximated by the quadratic function. The structual form of this equation is defined as the relationship between average cost per ton and output of sugarcane estimated at various levels of farm production. The cost variable includes: 1) variable and fixed capital costs; 2) family and hired labor; 3) custom field work; 4) land costs; and 5) other costs such as fertilizer, herbicides and seedcane. Output of sugarcane refers to harvested sugarcane prior to its processing at the mill. Pre-milling tonage is used because sugarcane growers make management decisions based on the production of sugarcane rather than processed raw sugar.

Three forms of the quadratic equation are estimated as shown in Table 4.8. Equation A refers to the production crop period ending in 1977; equation B, to the crop production period ending in 1980; and equation C, a weighted

average of both years. The dependent variable is average cost per ton and the independent variable is output in sugarcane tons. The quadratic equation is expressed as:

$$AVECOST = \alpha + \beta_1 Y_1 + \beta_2 Y_2^{\ 2} \qquad (4.5)$$

where

AVECOST = average cost per ton of sugarcane

α = intercept term

Y_1 = output in sugarcane tons

$Y_2^{\ 2}$ = output in sugarcane tons squared

Table 4.8 identifies the estimated coefficients of the quadratic equation with respective standard errors and levels of statistical significance. The signs of the parameters which are negative for β_1 and positive for β_2 in equations A, B and C indicate that minimum cost values are present. Although the statistical tests as noted by the standard errors of the coefficients, t-ratio values, R^2 and F values are not within the range of statistical significance, the forms and extent of the parameters of the equations appear to be adequate for this analysis. The intercept values as well as the estimated values of the equations are sufficiently within the expected norm of numerical acceptability.

Table 4.9 provides information on the unit cost values per ton paid at different levels of production measured in

TABLE 4.8

Estimated Coefficients of the Quadratic Function with Standard Errors

Variables	Parameters	Standard Errors
Equation A: 1977		
Constant	10.5310	(1.0859)***
δ_1	-0.0006014	(0.00048104)
δ_2	0.000000033571	(0.000000036113)
	R^2 = 0.0499	F = 0.997
Equation B: 1980		
Constant	13.0480	(1.0294)***
δ_1	-0.0002696	(0.0002698)
δ_2	0.000000010499	(0.000000011327)
	R^2 = 0.0345	F = 0.500
Equation C: Combined Data		
Constant	11.163	(1.0294)***
δ_1	-0.00030108	(0.00023191)
δ_2	0.000000015382	(0.000000010704)
	R^2 = 0.0304	F = 1.035

*** Significant at the one percent probability level.

output per ton of sugarcane. These values are estimated directly from the equations expressed in Table 4.8. The minimum cost per ton is $7.84 for the 1977 production period at a production level of 9,000 tons and $11.31 for the 1980 production period at 13,000 tons, with a weighted average of $9.69 for the two years at 10,000 tons. The results of the estimated values in Table 4.9 are plotted in Figures 4.1 to 4.3 which provide a visual approximation of the quadratic functions. Average cost per ton is indicated on the verticle axis and output in tons of sugarcane on the horizontal axis. These diagrams show the general shape of the curve depicted by the quadratic functions. They also provide additional information on the scatter of farm observations. Inefficient sugarcane growers are located above the curve and efficient growers on or below the curve.

The average cost curves, as estimated by the quadratic function in Table 4.8 and depicted in Table 4.9 and Figures 4.1 to 4.3, fall as output increases at small levels of output and rise within the range of large levels of output. As a result, minimum cost is attained where the lowest point on the average cost curve is nearest to the horizontal axis. This point can also be mathematically determined by differentiating the cost function, setting the values to zero and solving the remainder of the equation to determine the optimum level of output. Minimum cost for the 1977

TABLE 4.9

Average Costs of Sugarcane at Different Farm Production Levels Estimated by the Quadratic Function

Farm Size (acres)	Output (tons)	1977 ($)	1980 ($)	Combined Year ($)
10.5	1,000	9.96	12.79	10.88
21.0	2,000	9.49	12.55	10.62
31.6	3,000	9.03	12.33	10.40
41.1	4,000	8.66	12.14	10.20
52.6	5,000	8.36	11.96	10.04
63.2	6,000	8.13	11.81	9.91
73.7	7,000	7.96	11.67	9.81
84.2	8,000	7.87	11.56	9.74
94.7	9,000	7.84	11.47	9.70
105.3	10,000	7.87	11.40	9.69
115.8	11,000	7.98	11.35	9.71
126.3	12,000	8.15	11.32	9.77
136.8	13,000	8.38	11.31	9.85
147.4	14,000	8.69	11.33	9.97
157.9	15,000	9.06	11.36	10.11
168.4	16,000	9.50	11.42	10.29
178.9	17,000	10.00	11.50	10.49
189.5	18,000	10.58	11.57	10.73
200.0	19,000	11.22	11.71	11.00
210.5	20,000	11.93	11.85	11.30

growing season is estimated at $7.84 per ton of sugarcane produced at an optimum level of 8,957 tons. Since an average farm during this period produced at a level of 97.08tons per acre, the optimum farm size would be 92.27 acres with total production costs estimated at $70,222.

4.3.2 INTERPRETATION AND ANALYSIS

As indicated in Table 4.9, the minimum cost for producing sugarcane among independent growers for 1980 amounted to $11.31 per ton for an optimum size farm of 140.55 acres with an output of 91.35 tons of sugarcane per acre.

The results indicate that costs per ton of sugarcane were greater for farms smaller or larger than 140.55 acres. For example, the 1980 cost of production for a farm of 10.5 acres amounted to $12.79 per ton as compared to $11.31 per ton for the optimum sized farm. Likewise, the cost of production for a larger farm of 210.5 acres amounted to $11.85 per ton.

The analysis indicates that shifts in minimum cost and optimum production levels make it difficult for larger producers to remain in business. Unless these producers are able to adjust to higher levels of output by farm expansion, it is difficult to recover losses. Although the results indicate less efficiency for smaller farms, the smaller farms are in a better position than larger farms to offset

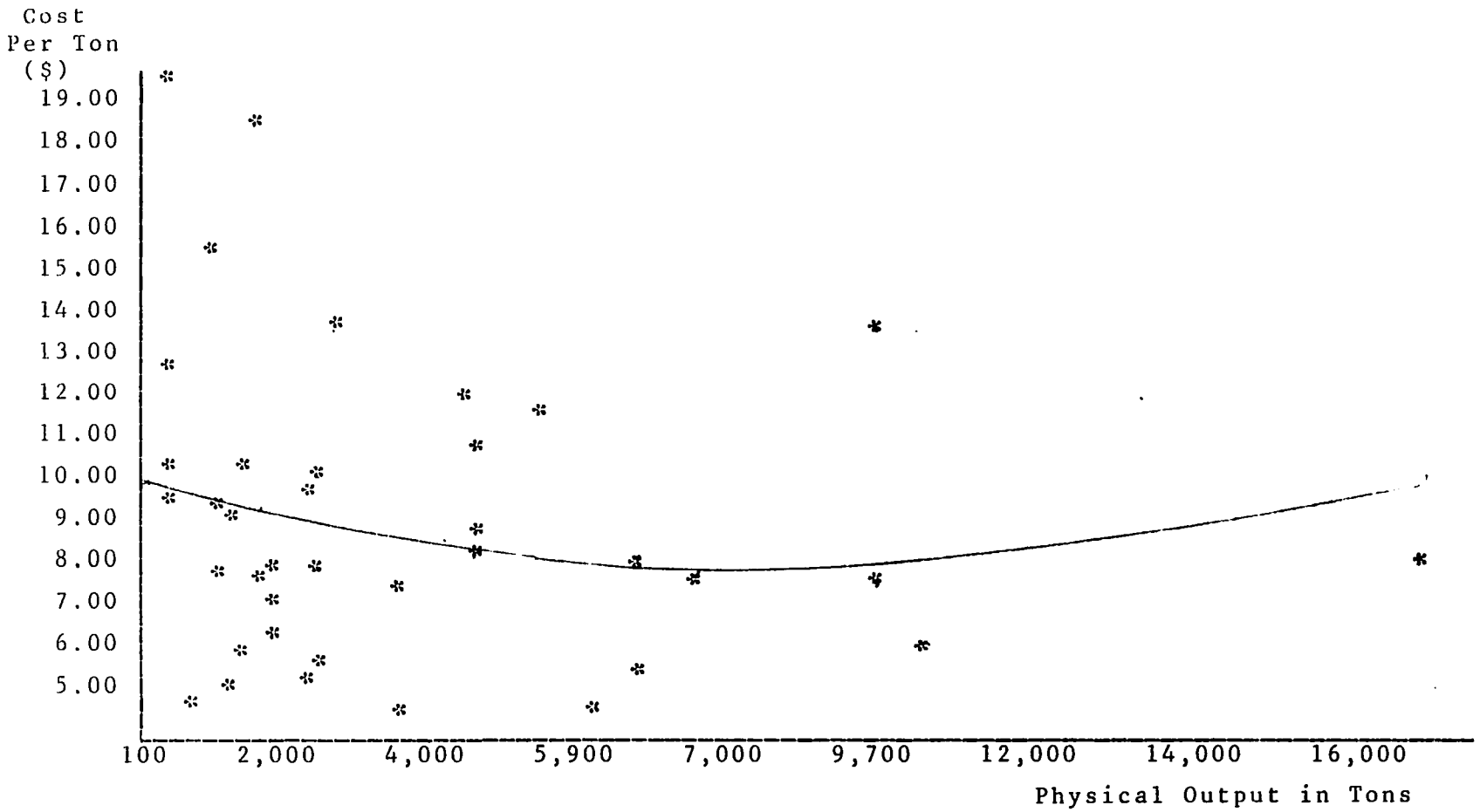

FIGURE 4.1. Estimated Quadratic Function with Scatter of Farm Observation for Independent Sugarcane Growers on the Hilo Coast (1977 Data)

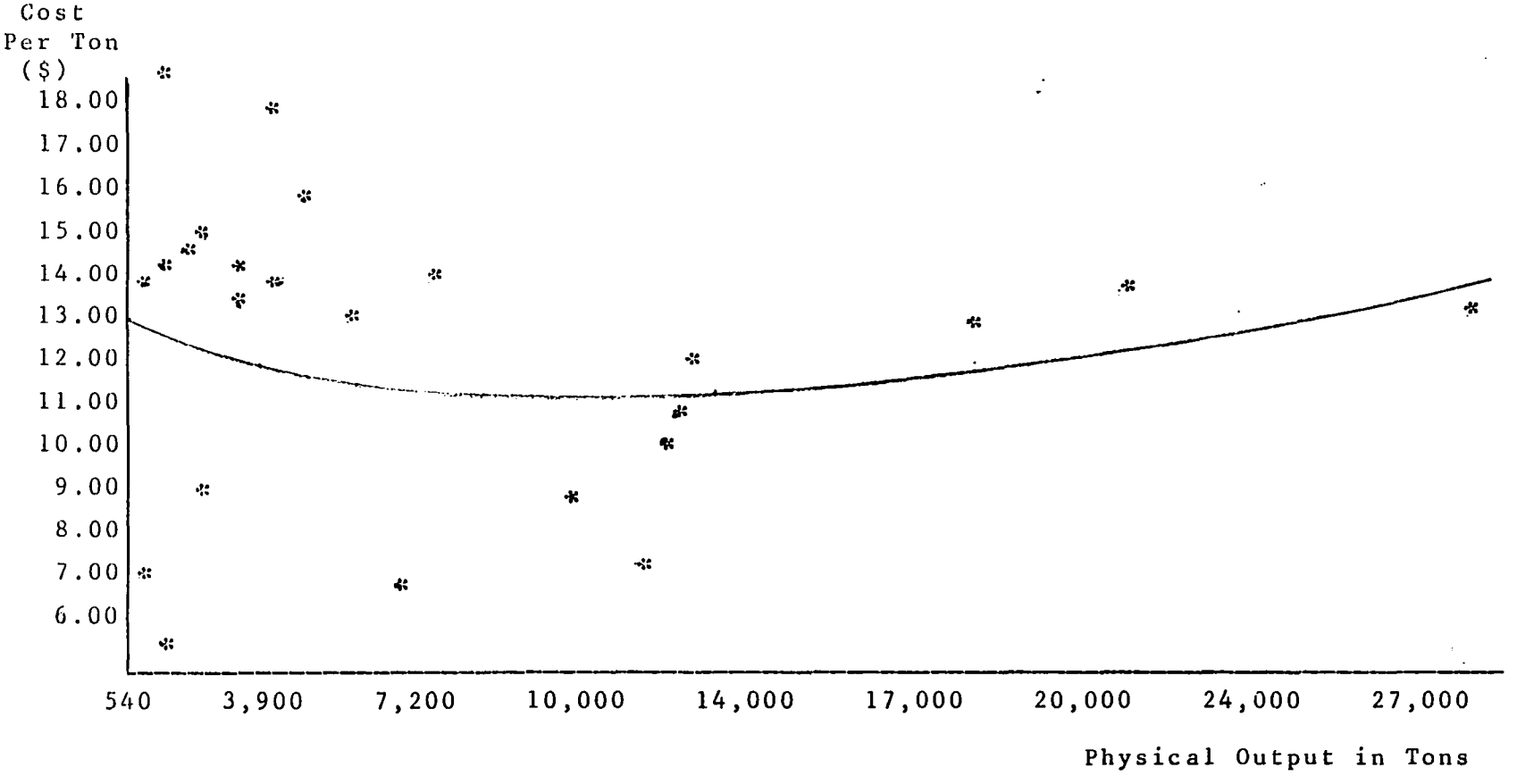

FIGURE 4.2. Estimated Quadratic Function with Scatter of Farm Observation for Independent Sugarcane Growers on the Hilo Coast

(1980 Data)

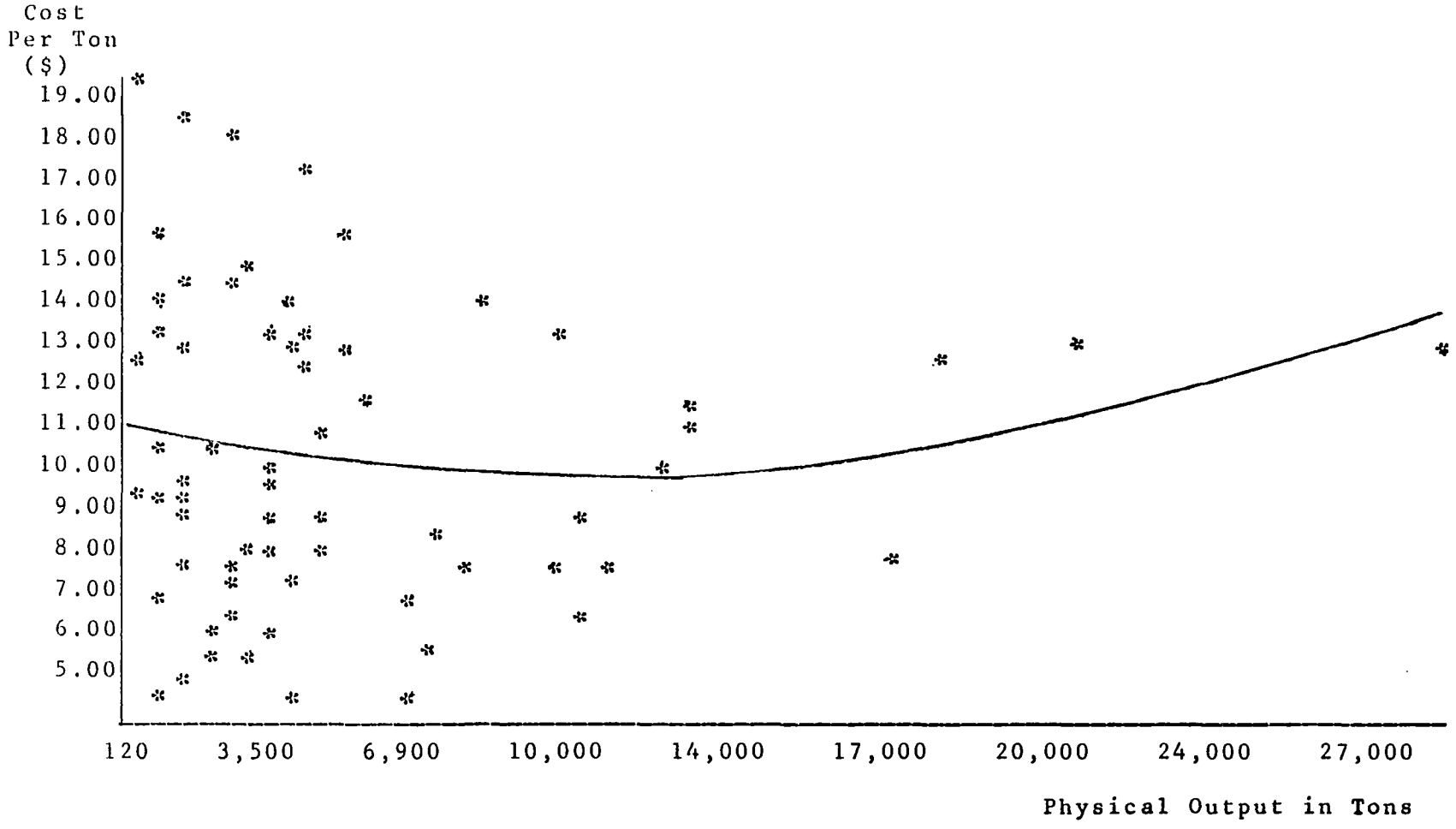

FIGURE 4.3. Estimated Quadratic Function with Scatter of Farm Observation for Independent Sugarcane Growers on the Hilo Coast

(Combined Data)

higher costs. A substantial amount of small farmcosts can be absorbed by family labor and/or subsidized by outside employment, whereas larger producers must rely on expanded capital outlay and/or contractual services. Under these conditions, it may be easier for smaller than larger independent growers to continue production in the short run even though unit costs are higher and marginal losses accur.

4.4 LOCUS OF LOWEST COST POINTS METHODOLOGY

4.4.1 BELOW AVERAGE ESTIMATES

Econometric functions are fitted to the scatter of observations and represent an average relationship between cost and output. It is also possible to approximate the economy of scale curve by fitting an envelope curve to the lowest points, rather than the estimated average of the scatter of farm observations. Essentially, it is an attempt to define the locus of lowest cost points that were obtained at various levels of output. In theory, the method should estimate the economies of scale curve insofar as the actual observations of farms include those which are efficiently organized and operated by sugarcane growers. It is, therefore, the objective of this section to select a representative number of farms that operate more efficiently than the average farms identified from the estimated regression equations presented in previous sections.

In order to simplify the analysis, four sugarcane farms were chosen with each producing at different levels of output and below the average costs shown in Figures 4.1 to 4.3. The costs reported by the four growers are shown in Table 4.10, indicating that total costs increase as levels of production increase. These costs include 1) variable and fixed capital costs; 2) family and hired labor costs; 3) land costs; 4) interest on loans; and 4) other variable costs. Table 4.11 shows the relationship between average costs and output measured in tons of sugarcane. The findings indicate that average costs decrease as farm size increases.

4.4.2 INTERPRETATION AND ANALYSIS

The amount of usage and cost of factors of production vary at different levels of farm production for each of the representative farms. The following discussion summarizes the differences shown in Table 4.10.

1. Captial costs are low for representative farms A through C and high for farm D. This is expected since larger producers require greater capital outlay than smaller producers.

2. Labor costs are low at all levels of farm size. It appears that family labor as well as hired labor costs are only partially reported and perhaps underestimated.

3. Custom field work costs may explain the low labor costs for representative farms B and C where other costs are high. However, this is not the case for farms A and D as reported costs are low. Capital intensive farms appear not to require a large amount of custom field work.

4. Land costs increase slightly but not proportionately as farm size increases. These costs include land rent and property taxes, only. A land charge for fee simple ownership is not reflected in the costs reported.

5. Interest payments on loans for variable inputs appear realistic. Aggregate interest costs are lower for smaller growers and higher for larger growers . It should be noted that interest on loans was not included in estimating the average cost of production by the quadratic function.

6. Other variable input costs as reported are much higher in comparison to other input categories and appear to be reflective of actual costs. Fertilizer makes up a large percentage of costs reported under other variable inputs. The amount of fertilizer purchased and applied in the production process can also affect yield which can effectively reduce the average cost of producing a ton of sugarcane.

Representative farm A in Table 4.11 indicates an average cost of $9.30 per ton compared to $10.88 per ton of a similar farm size estimated from the quadratic equation in

TABLE 4.10

Cost of Producing Sugarcane by Below-Average Independent Growers on the Hilo Coast

Factor Inputs	Representative Farms A 11.0 Acres ($)	B 27.0 Acres ($)	C 47.0 Acres ($)	D 95.0 Acres ($)
Capital	856	1,326	3,358	15,360
Labor	105	474	655	4,568
Custom field work	1,447	8,252	16,329	1,827
Land	1,033	1,578	2,358	3,317
Interest on loans	1,371	3,503	7,119	20,290
Other variable inputs	3,432	5,128	15,654	27,776
Total	8,244	20,261	45,473	73,138

TABLE 4.11

Output and Average Cost per Ton of Producing Sugarcane by Below-Average Independent Sugarcane Growrrs on the Hilo Coast

Category	Representative Farms A 11.0 Acres ($)	B 27.0 Acres ($)	C 47.0 Acres ($)	D 95.0 Acres ($)
Tons of sugarcane	885.98	2,197.40	5,757.50	10,864.81
Average cost per ton	9.30	9.22	7.89	6.73

percent for the lower cost producing farm. Representative farm B produces at $9.22 per ton, whereas the estimated quadratic figure is $10.40 per ton which shows a cost savings of 13.2 percent. Representative farm C averages $7.89 per ton compared to $10.04 per ton estimated from the quadratic equation. The cost savings of the lower cost farm is 21.4 percent. Finally, representative farm D with an average cost of $6.73 per ton is below the average cost of $9.70 from the estimated quadratic equation. This shows an average cost savings of 30.6 percent. In the final analysis, several factors appear to contribute to these cost savings, namely: 1) possible underestimates reported by the sugarcane growers themselves at the time of the survey; 2) different levels of output reflected in higher yields on a per acre basis; and 3) increasing economies of scale.

Results of several empircal approaches for analyzing economies of scale and optimum size of independent sugarcane farms are discussed in this chapter. Indications of both economies and diseconomies of scale as well as optimum farm size are identified by these methods. The results of the translog cost function under its restrictive form and various assumptions of homotheticity and unitary price substitution effects indicate evidence of economies of scale.

By investigating the effects of capital on output and selected factors of production, it was found that capital

expansion could benefit larger producers through economies of scale. As anticipated, smaller producers were less responsive to capital expansion and diseconomies of scale occurred at lower levels of production.

The quadratic function showed that average costs decreased as farm size increased, indicating economies of scale. This function also provided the basis for estimating optimum farm size by means of differentiating the equation. The findings of the quadratic function indicate that shifts in minimum cost and optimum production levels make it difficult for larger producers to remain in business. Smaller sugarcane growers, on the other hand, can continue production even though marginal losses occur.

Because of these findings, the hypotheses that there is no relationship between farm size and economies of scale, and that the optimum size of independent sugarcane farms on the Hilo Coast does not exist is rejected.

The results of the empirical analyses indicate that economic efficiency can be attained by expanding the farm to a certain level of production. However, in recommending the range of economic efficiency as defined by economies of scale, it is necessary to select one model from those analyzed that best explains this relationship. The translog cost function was found to be more acceptable than the quadratic function in the analysis. Since the translog cost function shows that economies of scale are present up to 50

acres in farm size, independent sugarcane growers producing less than 50 acres could consider expansion to increase efficiency. The reasearch findings indicate, on the other hand, that expansion of farms producing 50 acres or greater would probable not result in greater efficiency.

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1 SUMMARY

This study on economies of scale and optimum size of independent sugarcane farms on the Hilo Coast was undertaken subsequent to two earlier publications analyzing the costs of these farms. The findings showed that there were large variations in size of farm and major differences in the organization and management of sugarcane production. Such variations in farm size suggest that a study should be undertaken to compare the performance of farming operations among growers having similar as well as different sizes and types of units.

In order to accomplish this objective, three econometric models were developed, tested and analyzed, namely: 1) the transcendental logarithmic cost function, commonly known as the translog cost function; 2) the modified Cobb-Douglas function with variable production elasticities; and 3) the quadratic function. In addition to the econometric models, a fourth method was used to approximate scale economies by fitting an envelope curve to the locus of lowest points over the range of observations.

The analysis of the translog cost function estimated without the share equations under the restrictions of

homotheticity, homogeneity and unitary elasticities of substitution provided varying results. Scale economies remain constant as farm size increases for the homogeneous models with and without consideration of unitary elasticities of substitution (EOS). Positive economies of scale are present at all levels of production. For the homothetic models with and without EOS, scale economies increase up to 99.9 acres and decrease at higher levels of production. The non-homothetic models, on the other hand, indicate positive economies of scale up to 49.9 acres and negative economies of scale beyond that size. However, in both the non-homothetic and homothetic models with and without EOS, highest scale economies are achieved in lower levels of farm production of less than ten acres.

The modified Cobb-Douglas function with variable production elasticities is estimated by imposing a capital intensity index variable into the equation. This index variable measures the flow of capital services related to factors of production in dollars per acre of land. The results of the estimated equation indicate that partial elasticities of land, labor and capital as well as returns to scale are influenced by capital intensity of production. Economies of scale correspondingly increase as more capital-intensive techniques are adopted by sugarcane growers. Conversely, sugarcane production with less capital-intensive techniques is not subject to positive

economies of scale as determined by the modified Cobb-Douglas function.

The quadratic function offers additional information by determining minimum cost and optimum levels of the farm operation. The average cost of producing sugarcane is explained as a function of output. The outcome of the estimated equations for the two production periods in question indicate an upward shift in both minimum cost and output levels. Farm cost more than doubles for the optimum farm size from one period to the next. In order to maintain an optimum level of production, it would be necessary for sugarcane growers to expand farming operations.

The locus of lowest points method resulted in the selection and analysis of four representative sugarcane farms that were producing below the average cost curve at different levels of output. It was assumed that these farms were producing at an efficient level of production. However, in the final analysis, it was found that several factors contributed to these cost savings, namely: 1) possible underestimates of input costs reported by the sugarcane growers themselves at the time of the survey; 2) efficient level of output reflected in higher yields on a per acre basis; and 3) increasing economies of scale.

5.2 CONCLUSIONS

Several conclusions are arrived at from the preceding analyses on economies of scale and optimum farm size of independent sugarcane growers on the Hilo Coast. They are listed as follows according to the methodology presented.

1. Translog Cost Function identifies total cost relationships at various input prices. Marginal economies of scale are highest for small-sized farms. As farm size increases, scale economies increase at a decreasing rate up to 49.9 acres. Thereafter, diseconomies of scale occur at increasing rates.

2. Modified Cobb-Douglas Function with variable production elasticities utilizes a capital intensity index. The analysis shows that economies of scale increase as capital flow increases. Capital expansion, however, should be limited to production levels not exceeding 50 acres as the findings of the translog cost function indicate.

3. Quadratic Function explains average cost per ton of sugarcane as a function of output. Minimum cost and optimum output levels are attainable by larger producers because of efficiencies resulting from capital expansions. However, extensive shifts in costs from one production period to the next explain why it may be uneconomic for some independent sugarcane growers to continue farming. In these cases, it would be more feasible for several growers to produce

sugarcane as a unit, thereby reducing expansion costs brought about by purchasing addtional outlays of capital.

4. Locus of Lowest Points method analyzes four representative growers. This method is expected to better identify efficient sugarcane farms than average cost curves estimated by econometric functions.

5.3 RECOMMENDATIONS AND NEED FOR FURTHER RESEARCH

Data utilized for the study are limited in that they only provide information from two production periods. It is recommended that future studies be based on more estensive data collected through a combination of time series and cross sectional surveys. Periodic surveys need to be taken of independent sugarcane growers every three to five years to reflect changes in technology and economic conditions.

Information gathered from future survey should include input costs as well as the prices paid for purchasing factors of production. With adequate variation of input prices, it should be possible to estimate both the translog cost function and the cost share equation simultaneously.

Future studies should also consider 1) the effects of processing and marketing costs as they relate to economies of scale and optimum farm size; 2) the choice of raw sugar versus sugarcane as it affects farm efficiency; 3) the length of the planting cycle as it influences growth and output of raw and cane sugar; and 4) other non-controllable

factors such as topography, elevation and weather at the time of harvest.

Each of the three econometric models chosen for the analysis indicates that economies of scale are present and cost efficiencies can be estimated for the independent sugarcane farms on the Hilo Coast. Each methodology, however, provides different information and insight into the nature of the problem. Since no one method provides conclusive information on all possible explanations of economies of scale and optimum farm size, it is recommended that further research be carried out on comparative studies of these and other types of econometric models.

APPENDIX

Questionnaire

HILO COAST INDEPENDENT SUGARCANE GROWERS
Department of Agricultural and Resource Economics
University of Hawaii
in cooperation with the
Hawaii State Department of Agriculture

SECTION I. Land Use Entire Farm

1. How many acres of sugarcane, other crops, and total land were in your operation in 1979 and 1980?

Land Use	Total Acres 1979	1980
Sugarcane		
All other crops		
Total acres in operation ...		

2. Did you harvest any sugarcane in 1980?

Check Yes No

Enumerator note:

If no sugarcane was harvested in 1980, conclude interview.
If yes, select sample fields and continue interview.

Section II. Land Tenure - Sample Lots Only

1. Of the sample sugarcane acres harvested in 1980, how many were:

	Field #1 lot no. ____ acres	Field #2 lot no. ____ acres
a. Owned?		
b. Cash rented? ...		
c. Share rented? ..		
d. Total sugarcane?		

2. If any sample acres were used, what was the average cash rest per acre, per year? ..... $

3. If sample lots are leased, list names of leasors:

_____

_____

Section III: Planting, Harvesting, and Production Sample lots only

1980 HARVEST	Date Planted	Date Closed-in	Date Harvested	Tons cane harvested of sugar	Tons cane harvested for seed	Seed value dollar
Field 1						
Field 2						
Total						

SECTION IV: Labor Expense Worksheet

This section if for recording the labor used for various operations of the sample lot(s). Where exact figures are not available, use best estimate.

Operation	Lot no.	Date of work	Acres Oper.	Man-Hours Fam.	Man-Hours Hired	Rate per hour	Labor-dollars Oper.	Labor-dollars Fa.	Labor-dollars Hired
1. PREPARING AND PLANTING, CLEARING, CUTTING LINE, PLANTING, COVERING SEED									
2. REPLANTING									
3. SEED PROCUREMENT, CUTTING AND HAULING									
4. CULTIVATION									
5. SPREADING FERTILIZER									

Operation	Lot no.	Date of work	Acres	Man-Hours Oper.	Fam.	Hired	Rate per hour	Labor-dollars Oper.	Fa.	Hired
6. FERTILIZER PROCUREMENT, HAULING										
7. SPRAYING HERBICIDE										
8. HERBICIDE, HAULING WATER AND MATERIAL										
9. BORDER WEED CONTROL, FIELD OPENING										
10. LAND IMPROVEMENT										
11. CANE HARVESTING										
12. CANE HAULING										

SECTION V: Supply Expense Worksheet

no.	Per unit	Plantation	Operator
1. Field #1			
SEEDCANE			
Field #2			
Total			
2. Field #1			
FERTILIZER			
Field #2			
Total			
3. Field #1			
HERBICIDES			
Field #2			
Total			

SECTION VI: Expenses for Constant and Custom Work

Now we need some information about expenses for any contract or custom work done for the sample lots.

Type of operation	Cost of custom or contract work Not done by plantation Field #1	Not done by plantation Field #2	Done by plantation Field #1	Done by plantation Field #2
a. Preparing and planting.				
b. Replanting....				
c. Cultivating...				
d. Fertilizer....				
e. Spraying.....				
f. Harvesting....				
g. Pest control..				
h. Transporting..				
i. Road maintenance..				
Total.....				

SECTION VII: Summary of Expenses

LABOR Enumerator note: Totals for this summary come pages 3-5.

Type of Operation	Operator, family and hired labor Number of man-hours		Dollars	
	Field #1	Field #2	Field #1	Field #2
			Dollars	
a. Preparing and planting...				
b. Replanting.....				
c. Cultivating.....				
d. Fertilizer.....				
e. Spraying.....				
f. Harvest, hand...				
g. Harvest, machine				
h. Pest control....				
I. Transportion....				
Total.....				

SECTION VII: Summary of Expenses - Continued

LABOR Enumerator note: Totals for this summary come pages 3-5.

Type of Operation	Operator, family and hired labor Number of man-hours		Dollars	
	Field #1	Field #2	Field #1	Field #2
			Dollars	
a. Seed cane				
b. Fertilizer ...				
c. Herbicide				
d. Haul, fertilizer ...				
e. Haul, herbicide				
f. Haul, other				
g. Water				
h. Barrels				
Total				

SECTION VIII: Land, Buildings, Equipment, and Depreciation Expenses - Entire Farm

Now we need to know some information on your costs of land, buildings, improvements, equipment and depreciation for your entire operation.

1. Property and depreciation

Item	Year purchased	Original cost (dollars)	Est. Life (year)	Depreciation Reserve	1980 crop	Gain on sale	Loss on sale
a. Land							
b. Roads Fields							
c. Buildings							
d. Equipment and tools							
Tractor							
Truck, pick-up							
Truck, flat-bed							
Line opener							
Disc							
Fertilizer attachment							
Spray machine							
Backpacks							
Other:							

SECTION VIII: Land, Buildings, Equipment, and Depreciation Expenses - Entire Farm - Continued

2. Farm machinery operating costs - entire farm.

Expense	First year	Second Year
	Dollars	
a. Repairs, labor		
b. Repairs, material		
c. Equipment parts		
d. Fuel and oil		
e. Tires and tubes		
f. Small tools		
g. Personal car use		
h. License and insurance ..		
Total		

SECTION VIII: Land, Buildings, Equipment, and Depreciation Expenses - Entire Farm - Contined

3. Farm overhead expenses.

Expense	First year	Second Year
	Dollars	
a. Land rest		
b. Real property tax		
c. Property insurance		
d. Gross income tax		
e. Financial and legal fees		
f. Association dues		
g. Business and legal fees.		
h. Workmen's compensation .		
i. Temporary disability insurance		
j. Social security and unemployment tax		
k. Licenses (gross income).		
l. Keogh plan		
m. Depreciation, equipment.		
n. Depreciation, other		
Other		

SECTION IX: Summary of Returns, and Marketing and Processing Expenses - Sample Lots

Net proceeds from crop	Field # 1		Field # 2	
	Tons	Revenue	Tons	Revenue
Sugar, 96				
Molasses				
Other credits				
Gross Proceeds				
Marketing expense				
Processing fees				
Retains				
Total Expenses				
Net Proceeds from Crop .				

Contract terms and company charges for services:

Delivery point _____

Harvesting charges, per ton _____

Hauling charges, per ton _____

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