A PRODUCTION FUNCTION ANALYSIS OF PADDY FARMING IN SRI LANKA

by

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ABSTRACT

The primary purpose of this thesis was to analyse underlying input-output relationships in paddy farming in Sri Lanka. Cross-section study data involved 107 paddy farms from five major paddy districts. The period under study was the 1972-73 Maha paddy season. Data collection was based on farm record keeping.

Production function analysis was applied in the study. Factor shares and least squares regression methods were used to estimate production functions. Results from the factor shares method were not completely satisfactory in the context of the study. Accordingly the least squares method assumed most importance in the analysis. Both multi-linear and Cobb-Douglas functions were fitted to the data and the latter gave the best statistical fit. Functional analysis was also used at the regional level. The dummy variable technique and discriminant analysis identified two regions within the main sample. Productivity index comparisons were made among districts composing the two regions.

The analysis with respect to the over-all sample indicated the presence of resource mis-allocation on paddy farms. Typical paddy farmers were found to be employing land and draft services efficiently when all other resources remained at geometric mean levels of use. Nevertheless, under similar conditions of geometric mean level resource use, fertilizer and labour were not used intensively enough. In particular fertilizer was seriously under-utilized. Calculation of expansion path resource combinations and various productivity estimates confirmed these results. Therefore, the analysis showed that paddy output can be

increased by more intensive application of fertilizer and labour. The latter calls for intensive practices such as transplanting and manual weeding. But study findings also suggested the existence of labour shortages during peak periods of paddy farming.

Marginal productivities of fertilizer and labour in both low and high response designated regions, showed once again that at geometric mean levels of resource application, they were substantially higher than their prices. In the regional analysis the draft service input (including animal and tractor services) was found to be typically over-utilized in the low response region and under-utilized in the high response region. The latter points to a shortage of draft services in the high response region which can act as a constraint to increased paddy production. Expansion path resource combinations were also calculated for each region to act as guide-lines for efficient resource application.

Analysis at the district level for ascertaining the productivity of all inputs other than land in paddy farming, showed that Polonnaruwa district was twice as productive as Kurunegala district. In the same context Hambantota came close to Polonnaruwa, whereas, Kandy and Colombo closely matched Kurunegala.

TABLE OF CONTENTS

LIST OF TABLES

TABLE Page

LIST OF FIGURES

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CHAPTER I

INTRODUCTION

A. PROBLEM SETTING

1. The Agrarian Sector and Economic Development in Sri Lanka

The agricultural industry contributes about one-third of Sri Lanka's Gross Domestic Product and provides employment for half the country's total labour force. This study deals with an economic analysis of resource use in rice production, a major agricultural activity in Sri Lanka. Along with the three main export crops--tea, rubber, coconut--rice occupies a predominant place in the economy of the island. The output of these four agricultural crops is still the major influence in Sri Lanka's crucial balance of payments problem. Therefore, concern has been repeatedly expressed by the planners over the lagging rates of agricultural development, and this has been particularly true of the subsistence sector. The task of supplying domestic food requirements is solely dependent on the subsistance or peasant sector, in which rice farming is the most important enterprise.

In spite of all the efforts to develop the subsistence sector its response has been far from satisfactory. As is common in other developing countries, slow improvement in the economic welfare of the peasantry has caused frustration among planners. The failure of this sector is clearly demonstrated by recurrent food scarcity crises. The disappointing performance of subsistence agriculture has created a tremendously large burden on the already strained economy. As a result the government has been forced to curtail or postpone other high priority development programmes in the non-farm sector of the economy.

Although some degree of controversy still exists as to whether emphasis should be placed on agriculture or industry, it is generally agreed that the former has a critical role to play in the process of economic development in countries like Sri Lanka, particularly in the initial stages of growth. In a developing economy, a growing agricultural industry can be an important source of food supply for the population and it can also contribute much to the growth of industry by supplying raw materials, labour and capital.[1] Furthermore, in an economy characterized by low-productivity labour and an extreme shortage of capital, agriculture can play a crucial role in the overall development effort by providing an opportunity for economic growth with relatively little physical capital.

Empirical evidence seems to suggest that the income elasticity of demand for agricultural products in developing countries is so high--three to four times more than in developed countries--that a stagnating agricultural industry can restrain economic growth by causing food shortages.[2] This situation can also lead to inflationary food prices or

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[1] Peter T. Bauer and Basil Yamey, The Economics of Underdeveloping Countries, Chicago University Press, 1971, pp. 235-36.

[2] Earl O. Heady, A Primer on Food, Agriculture and Public Policy, New York, Random House, 1967, pp. 9-10.

utilization of foreign exchange for importation of food. If the latter takes place it will be at the expense of capital goods and raw materials needed for the industrial sector.

Many investigations into factors contributing to the agricultural lag in developing countries have yielded a wide variety of results.[3] In general, these analyses have tended to show at least four major sources of problems--economic, technological, socio-cultural and political--contributing to the situation. The economic factors involve considerations such as inadequate credit facilities, improper marketing mechanisms, deficient supply of inputs and inefficient allocation of available resources. The quality of inputs and outputs, the ease with which inputs can be substituted for another, and the existing stock of production techniques, can be considered as some of the technological factors. The socio-cultural aspects include the response and attitudes of people towards change, tenure and ownership patterns of traditional societies and similar institutional aspects. The final category dealing with political factors, includes types and efficiency of taxation, quality of social services such as transportation, health, and agricultural extension services, etc., and also the efficiency and responsiveness of the civil service and political leaders to the needs and aspirations of the people. While admitting that this list does not provide an elaborate and clear-cut classification, it, nevertheless, indicates some of the variety and

[3] For an interesting discussion see R. Wharton Clifton, Jr., Subsistence Agriculture and Economic Development, Chicago, Aldine Publishing Co., 1970.

complexity of problems of agricultural development in a developing economy like Sri Lankas.

Thus, it is apparent that there can be numerous approaches to development of the peasant agricultural sector in a growing economy. Broadly speaking, these approaches can be divided into two categories, economic and non-economic. While the non-economic consideration might entail altering the existing social and political framework of society, the economic factors would basically involve the manipulation and re-shuffling of existing stocks of resources in the most efficient manner and supplying additional resources wherever it was deemed necessary.

Economic development is primarily connected with increasing the number of permanent annual income streams produced by the economy. With regard to rice production, this can be accomplished by shifting the production possibility frontier of the industry outwards and more efficient allocation of the existing resource inputs, or by some combination of both. The former method involves application of more conventional and non-conventional resources as well as introduction of modern rice production technologies, either separately or in combination. The latter method involves optimal resource and output combinations in the context of marginal rates of substitution and marginal rates of transformation.

2. Role of the Rice Industry in the Economy of Sri Lanka

Sri Lanka can be described as having a dual agricultural economy in which a commercial, export-oriented plantation sector exists alongside a traditional, subsistence-oriented, peasant sector. The plantation sector deals with the three major export crops, while the subsistence sector is associated with domestic food supply and is mainly concerned with rice production. Prior to independence in 1948, rice production had been neglected in favour of the export crops. But since independence, successive governments have taken steps to increase domestic rice output.

The importance of rice in the economy of Sri Lanka is evident from data presented in Appendices 4 and 5. Appendix 4 shows a total cultivated area of 3.5 million acres under four major crops namely rice, tea, coconut and rubber, of which rice alone occupies 1.3 million acres. Appendix 5 shows that employment generated by the rice industry accounted for 41 per cent of total employment provided by the four major crops. Hence, rice occupies a predominant position in the land-use pattern and it is a major source of employment in Sri Lanka. The significance of rice in the economy stems from the fact that it constitutes the staple diet of a population of 13 million. Food consumption data for Sri Lanka shows that in the period 1963-64, rice and wheat jointly accounted for 97.5 per cent of grain consumption and 55 per cent of total calorie intake. As the calorific value by weight of these two grains is almost identical, a high degree of substitution in consumption can exist between them. However, at the usual relative prices rice is preferred to wheat at all income levels. This fact is clearly evident from the relative per capita consumption figures of wheat and rice. In 1966-67 total per capita consumption of both rice and wheat was 123.6 kgs., of which rice accounted for 103.5 kgs.

The present state of under production of rice has become a substantial burden on the national economy. For instance in 1969-70, total direct and indirect subsidies towards provision of rice to consumers amounted to Rs. 556.8 million, which was 19 per cent of total government revenue. This included a direct subsidy of Rs. 219.6 million to producers and Rs. 237.2 million for consumers. Therefore, these facts indicate the necessity of expanding domestic rice output by way of suitable adjustments in the industry. An increase in rice output would result in the saving of a considerable amount of foreign exchange through import substitution. This saving could be used for importing the capital goods necessary for industrial development.

Therefore, an investigation of resource-use efficiency in rice production in Sri Lanka is of major interest. Through economic analysis it is possible to make resource adjustment recommendations for this commodity, and this information helps to form a basis for policy directives. In this regard, interest would mainly centre on measures of marginal contribution to total output by different resources, elasticity of output with respect to individual inputs employed and the productivity differences between agro-climatic areas.

B. OBJECTIVES

The primary purpose of the study is to analyse the economics of production on paddy farms in Sri Lanka and ascertain the nature of corrective measures for increasing paddy output in the major areas.[4] The analysis is based on the hypothesis that agricultural resources were not

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[4] Specific areas are given in Chapter IV.

being used efficiently in these areas. In other words it was postulated that agricultural resources could be reorganized to generate a greater output of paddy with the same levels of inputs, or, conversely, the same output could be obtained with fewer resources. The other objectives of the study are to identify resource utilization patterns and to provide guidelines for the efficient use of agricultural inputs in the areas under consideration. More specifically these objectives can be defined as:

i. to determine productivity coefficients for relevant resources in paddy production in selected areas;

ii. to measure the gap between existing and optimal levels of resource use on sample farms and, thereby show the degree of economic efficiency of resource utilization in 1973 at the farm level;

iii. to determine appropriate economic adjustments in the existing stock of resources on farms in the areas studied, from the standpoint of profit maximization.

The study for attaining these objectives was based on farm records maintained by 107 paddy farmers for the 1972-73 Maha season rice crop in five selected districts. The main research technique employed was production function analysis, using factor shares and multiple regression, whereby, the associative effects of inputs are expressed in terms of regression coefficients.

C. THESIS ORGANIZATION

The study is divided into six chapters. The present chapter provides introductory information for the analysis, while the second chapter surveys relevant literature. Chapter III deals with fundamental theoretical concepts relating to resource allocation and appropriateness of methodology. Chapter IV discusses the conceptual model, the nature of variables and the source and collection of data. Chapter V reports on the research analysis and results. The last chapter presents a summary of findings and discusses their relevance to current problems. It also makes recommendations to policy makers and suggests areas for future research.

CHAPTER II

LITERATURE REVIEW

A. EARLY DEVELOPMENTS IN PRODUCTION FUNCTION ANALYSIS

A number of early economists such as Smith, Ricardo and Malthus hypothesized the general nature of the production function. Since then much literature has been added regarding application of formal production functions to farm studies, both at the micro and macro level. One of the first economists to hypothesize an albegraic form for the physical agricultural production function was Knut Wicksell. He inferred that increasing returns to capital and labour inputs were possible when fertilizer is added to nutritionally deficient soils. Thus, he showed that agricultural output is dependent on the quantity and quality of resources used to obtain it. He further showed that agricultural output was clearly dependent on land, labour and capital inputs and the relationship could be expressed in terms of a mathematical equation. He demonstrated that if the inputs for a given period of time are denoted by X_1, X_2, X_3 and the corresponding total output by P, the production function can be defined as:

$$P = f\ (X_1,\ X_2,\ X_3) \qquad [2.1]$$

Although Wicksell was the first to hypothesize the mathematical basis of production functions, the first empirical estimation of the parameters of a production function was attempted by Charles W. Cobb and Paul H. Douglas in 1928.[1] The type of function used in their study is generally known as the Cobb-Douglas production function. However, the origin of this particular function can be traced to Wicksell who mentioned it in a footnote as having the following formulation:

$$P = X_1^{\alpha} X_2^{\beta} X_3^{\gamma}$$

Wicksell goes on to state that the coefficients for this type of function might add up to unity, implying a state of constant returns to scale. In their study, Cobb and Douglas fitted a function, similar to that of Wicksell's to the data on American manufacturing industry for the period 1899 to 1922. This work constituted the first formal estimation of a production function using time series data. The form of the fitted function was $P = b\ L^{k}\ C^{k-1}$, where P was the predicted output over the period, L was labour employment and C was the capital input in the industry. The function derived from the data was $P = 1.01\ L^{.75}\ C^{.25}$. The selection of this particular functional form, subject to the constraint that the coefficients add up to unity, was presumably due to their wish to assign the total product to the two factors of production. If the sum of the coefficients were greater or less than unity, the total product would be greater or less than the total amount inputed to the two factors by way of marginal productivities. A complete distribution of product among inputs can be explained in terms of Euler's theorem of product

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[1] Charles W. Cobb and Paul H. Douglas, "A Theory of Production," Am. Econ. Rev., 18: 1928, pp. 139-156.

exhaustion, which states that under conditions of linear homogeneity the total product will be just exhausted when marginal products are inputed to the resources.

In their later studies, however, Douglas and co-workers relaxed the restraint of forcing the sum of elasticities of the individual resources in the function to be equal to one and employed the functional form, $P = b\ L^k\ C^j$, where the coefficients j and k could take any non-zero value. It is this type of log-linear power function which is commonly referred to as the Cobb-Douglas production function. The latter is widely used in production function analysis and in numerous other quantitative estimation procedures in economics. The popularity of this specific functional form can be attributed to the relative ease with which coefficients are computed, convenience of interpreting the elasticities of production and also the fact that the estimation of parameters permits more degrees of freedom than some other algebraic forms.

A major attempt at determining a production function from farm data was reported in 1942. In this study Tolley, Black and Ezkiel,[2] based their estimation on cross-sectional observations of enterprises. The input categories were specified as labour, fertilizer and feed. The units of measurement were both in physical and value terms. The data were used to estimate a hog production function and linear functional forms were used. From the results they concluded that diminishing marginal productivities of resources prevailed.

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[2] H. R. Tolley, J. D. Black and M. J. Ezkiel, Inputs as Related to Output in Farm Organization and Cost of Production Studies. Technical Bulletin 1277, USDA, Washington, D.C., 1942.

A study by Tintner[3] in 1942 used data from 609 farms in Iowa State. Six independent variables were selected as affecting farm output. In addition to land and labour Tintner included farm improvement expenditure, liquid assets, working assets and cash operating expenses as variables to explain output. The estimated function was not constrained with respect to the sum of the elasticities. Decreasing returns to scale were shown by the estimated Cobb-Douglas function, the sum of the input coefficients coming to .86.

Heady published his first study on production function analysis in 1946.[4] This was based on survey data from a random sample. The design of the sample was such as to give unbiased estimates of certain livestock and crop inventories. The input variables used by Heady were real estate, labour, machinery and equipment and livestock expenses. Both physical and monetary values were used in measuring variables as in the case of Tintner. To obtain the best results Heady pointed out that preliminary research should be carried out to determine correlations among the factor inputs. He mentioned that if high correlations are present between factor inputs they may lend themselves to combinational assessment and totalling. Heady used a Cobb-Douglas function in his analysis which explained about 77 per cent of the variance of output.

B. DEVELOPMENTS IN PRODUCTION FUNCTION ANALYSIS IN AGRICULTURE

An important development in recent production studies has been the concept of duality. Duality in relation to production theory is

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[3] G. Tintner, "A Note on the Derivation of Production Functions from Farm Records." Econometrica 16: 1944, pp. 295-304.

[4] E. O. Heady, "Production Functions from a Random Sample of Farms." J. Farm. Econ: 28: 1946, pp. 989-1004.

analogous to dual and primal problems and solutions in mathematical programming. In relation to production functions duality can be explained as follows: given either the minimum cost function or the production function and certain regularity assumptions, one can be uniquely determined from the other. This implies that producers operate as though prices are given and they attempt to minimize costs of producing a certain specified level of output. Recent publications by Diewert[5] and Danielson[6] explore applications of duality theory for the purpose of identifying and deriving production function relationships. It is sufficient to note here that the present study was not conceived as working from farm cost minimization assumptions towards defining the associated dual production function. Work published on this type of approach leads one to think that data problems quickly become prohibitive.

Another major advancement in production function studies is the development of alternative functional forms that can be used in empirical estimations. Important examples are the CES[7] (constant elasticity of substitution) and other flexible generalized function forms.[8] These

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[5] See: W. E. Diewert, "Application of Duality Theory." Discussion paper, No. 89, The University of British Columbia, 1973.

[6] R. Danielson, Three Studies in Canadian Agriculture. M.Sc. thesis, The University of British Columbia, 1974.

[7] For an important discussion of the CES function see: K. J. Arrow, H.B. Chenery, B.S. Minhas and R. M. Solow, "Capital-Labor Substitution and Economic Efficiency." Rev. Econ. Stat., Vol. 43, No. 3, Aug. 1961, pp. 225-249.

[8] Alain De Janvry, "The Generalized Power Production Function," Am. J. Agr. Econ. 54: 1972, pp. 234-237.

specific types of production function are very useful under certain circumstances and they often include the more simple functional forms as their special cases. For example the CES and generalized power (e.g., transcendental) functions include the Cobb-Douglas as their special cases.

The CES and other generalized functions can have clear advantages over simpler ones but in certain respects they can have limiting features too. For example the CES model allows the assumption of unitary elasticity of substitution in a Cobb-Douglas function to be relaxed. Nevertheless the CES function still imposes constant elasticity of substitution between pairs of independent variables.

With respect to the use of alternative functional forms a study of considerable interest was conducted by Salkin[9] in 1970, using a sample of paddy farms in Vietnam. He estimated Cobb-Douglas, CES and two other generalized forms of production function for his data. On the basis of results he concluded that the major difficulty in specifying production functions with sophisticated properties was that they may only be estimated approximately or by using very complicated techniques. Hence it can be noted that the production function models employed in the present study were of the simpler type. With the cross-sectional data available there seemed to be no distinct advantage in employing the more complex regression models.

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[9] J. S. Salkin, On the Specification and Estimation of Alternative Functional Forms in the Theory of Production. The Case of Rice Production in South Vietman. Unpublished Ph.D. Thesis, North Western University, 1970, p. 190.

Examination of recent literature provides clear evidence that the production function technique as a tool for analyzing farm problems has been continuously improved upon. Since the early fifties many studies have been published by Heady and other research workers in various aspects of production function analysis, incorporating more and more theoretical concepts. As a result, the objectives, analytical tools and research methodology of the technique are highly developed and related findings often provide a greater basis for action than results from many other areas in applied economics.[10] This has been made possible by the use of advanced statistics, mathematics and computers.

A remarkable feature of recent developments in production function analysis has been the broadening of research objectives. The early studies seem to have been mainly concerned with individual farm analysis. Now the recognition of multiple objectives for production function analysis has increased its use.

Multiple objectives of production function analysis have concerned[11] (1) providing guidelines to individual farmers for the efficient combination of resources, (2) analyzing the impact of public and private policies on the use of farm resources, (3) designing programmes

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[10] For a discussion of recent trends of development of the production function method see, G.L. Johnson, "Stress on Production Economics" in A.E.A. Readings in the Economics of Agriculture, Karl A. Fox and Gale D. Johnson (eds.), Richard D. Irwin, Inc., 1969, pp. 203-20.

[11] W. W. Wilcox, "Research in Economics of Farm Production," J. Farm Econ., August, 1947.

of adjustment in farming areas. Similarly, Warren[12] has stated the dual objective of production function analysis to be one of guiding individual entrepreneurs and acquiring broader understanding of the agriculture industry.

Since production functions have been traditionally associated with individual farm units, their application to industry-wide problems has sometimes been overlooked. Viewed in its entirety, agriculture is a competitive industry providing a situation where optimization of resource use by individuals leads to optimization conditions being achieved for society, which in turn implies a particular income distribution. This follows from the fundamentals of social welfare analysis[13] which state that under competitive conditions the social product would be maximized if, and only if, consumers maximize their utility and producers maximize their profits.

Problems will exist in applying the above optimizing criteria in cases where prices do not reflect competitive demand and supply conditions for products and factors. As a consequence, divergence will occur between the actual and free market prices in any segment of agriculture which is not competitive. In such cases special analytical approaches are required to evaluate costs and benefits in the private and public sectors of the economy. However, within the limits of these

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[12] S.W. Warren, Statistical Analysis in Farm Management, J. Farm. Econ., February, 1936.

[13] J.M. Henderson and Richard E. Quandt, Micro Economic Theory, New York, McGraw-Hill Book Company, 1958, pp. 254-292.

conditional forces, more efficient combinations of resources on individual farms augment social net product.

C. RECENT INVESTIGATIONS INTO RESOURCE ALLOCATIVE EFFICIENCY IN SUBSISTENCE AGRICULTURE

Attempts to study resource allocation by farmers in less developed countries (LDC's) are rather limited, although interest in this subject has been growing. The purpose of this section is to review the more important studies on this subject. In doing this specific attention will be paid to the basic assumptions underlying such studies, their general methodology and recent attempts to estimate allocative efficiency in subsistence agriculture.

Several important studies on allocative behaviour of farmers in traditional agriculture have concluded that results are in conformity with Schultz[14] hypothesis: "there are few significant inefficiencies in allocation of factors of production in traditional agriculture." In these studies the measurement of allocative efficiency is based on the assumption of profit maximizing behaviour on the part of peasant farmers.

Profit maximizing approaches have been criticized by some economists and sociologists.[15,16] Their arguments are based on two considerations.

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[14] T.W. Schultz, "Transforming Traditional Agriculture," New Haven, Yale University Press, 1963, p. 37.

[15] See: G. Myrdal, Economic Theory and Underdeveloped Regions. London, Duckworth, 1957; D. Seers, "The Limitations of the Special Case," Bulletin of Oxford Institute of Economics and Statistics 25: May, 1963, pp. 77-98.

[16] H. Myint, "Economic Theory and the Underdeveloped Countries," Jour. Pol. Econ., Oct. 1965, pp. 477-491.

Firstly, the Economic theory used in such analysis is established in relation to the particular social and institutional setting of the industrially developed countries. Therefore, it is argued that application of profit maximizing theory to underdeveloped subsistence economies has little meaning.[17] Secondly, in view of the important influence of risk factors in peasant farming systems, it is thought that profit maximization does not hold true.

Most objections to the assumption of profit maximization seem to be based on casual empiricism and observations. Arguing in favour of using hypotheses in economic research Friedman[18] states that:

> The evidence for a hypothesis always consists of its repeated failure to be contradicted, continues to accumulate as long as the hypothesis is used, and it by very nature is difficult to document at all comprehensively. It tends to become part of the tradition and folklore of a science revealed in the tenacity with which hypotheses are held rather than in any textbook list of instances in which the hypothesis has failed to be contradicted.

Therefore, quite apart from its acceptance or contradiction, it would seem that profit maximization can serve as a useful postulate on the basis of which research can proceed and be extended.

In view of the above criticisms it is important to discuss some of the studies which have shown that standard economic theory is relevant to the farmers in subsistence agriculture.

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[17] See: Michael Lipton, "The Theory of Optimizing Peasant." Jour. Dev. Studies, 1968, pp. 327-351.

[18] Milton Friedman, "The Methodology of Positive Economics," in Essays on Economics, M. Friedman, editor, Chicago, Univ. Chicago Press, 1953, p. 23.

Wise and Yotopoulous[19] conducted a rigorous empirical test of the economic rationality of subsistence farmers in Greece. By employing a number of econometric techniques, they relaxed the usual major assumptions underlying such analysis. They assumed that the farms did not have the same production function. The Cobb-Douglas type of production function employed had constant input coefficients, yet explicitly allowed for farm to farm variation in efficiency, technical knowledge and volume and quality of fixed factors. On the basis of their findings the researchers concluded that:

> . . . the idea itself of applying such a framework to traditional self-subsistence agriculture may sound quaint or eccentric! Still, the results are highly satisfactory and are in keeping with accepted economic theory: at least two-thirds of the variation in observed behaviour in our random sample of farms can be explained by <u>a priori</u> theoretical notions on profit maximization.[20]

The methodology employed in two major studies of resource allocative behaviour of farmers in LDC's,[21] shows that both of them used cross sectional data and regression techniques. The exact methodology used in such studies varies with specific approaches to handling different situations.

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19 John Wise and Pan A. Yotopoulous, "The Empirical Content of Economic Rationality: A Test for a Less Developed Economy," <u>J. Pol. Econ</u>. 77: Nov.-Dec. 1969, pp. 876-1003.

20 Ibid., p. 999.

21 D.E. Welsch, "Response to Economic Incentive by Abakaliki Rice Farmers in Eastern Nigeria," <u>J. Farm Econ</u>. 47: Nov, 1965, pp. 900-914, and V. Chennereddy, "Production Efficiency in South Indian Agriculture," <u>J. Farm Econ</u>. 49: Nov. 1967, pp. 816-820.

For example, Sahota[22] in his study involving three bodies of cross sectional data for three years, relating to six areas in India and eight farm groups, used a number of intercept and slope changing variables in the regression analysis. His study was limited to per acre data, since total farm data were unavailable. Hopper[23] selected 43 farms to observe resource allocation behaviour of traditional farms in India. The data were collected at the peak period of farming when factor markets faced the most competitive conditions.

The usual approach to judging efficiency of resource use from cross-sectional samples has been to employ techniques which do not consider risk factors associated with peasant farming. Dillon and Anderson[24] were probably amongst the first to incorporate risk consideration into the appraisal of resource use. In reporting their study, they stated that "risk attitudes must be an important element in understanding farmer behaviour in undeveloped agriculture." They presented a decision theory application of cross sectional production function estimates for assessment of allocative efficiency, maintaining that "What is needed is a measure of profit maximizing efficiency that has a direct economic interpretation yet depends on the statistical quality of underlying

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[22] Gian S. Sahota, "Efficiency of Resource Allocation in Indian Agriculture," Am. J. Agric. Econ. 50: Aug, 1968, pp. 584-605.

[23] David W. Hopper, "Allocation Efficiency in a Traditional Indian Agriculture," J. Farm Econ. 47: Aug, 1965, pp. 611-624.

[24] J. L. Dillon and J. R. Anderson, "Allocative Efficiency, Traditional Agriculture and Risk," Am. J. Agric. Econ., 53: 1971, pp. 26-32.

production function." In this study, the measure of allocative efficiency involved the expected opportunity loss of the average input allocation relative to the most profitable allocation under constant total expenditure. Dillon and Anderson's considerations regarding uncertainty about the production function have two main aspects. Firstly, even if a true function represented all farms the estimated function might differ from the true one owing to "pure noise" or unsystematic variations in the independent variables. Secondly, uncertainty affects the production function in the sense that estimated coefficients can be thought of as not being rigidly fixed. The study by Dillon and Anderson was based on the fact that these coefficients are not fixed, but only sample estimates having a particular probability distribution. In addition to being a valuable contribution to research methodology the study also provided partial support for the hypothesis of profit maximizing behaviour among farmers in subsistence agriculture. Furthermore, they concluded that their results are more favourable to the hypothesis of expected profit maximization than expected.

CHAPTER III

THEORETICAL CONSIDERATIONS

This chapter is divided into two sections. Section A is devoted to the more basic theoretical concepts of production and costs relevant to the present analysis. Section B deals with theoretical aspects involved in the selection and appropriateness of methodology used in the study.

A-1. PRODUCTION FUNCTIONS AND THE LAW OF DIMINISHING RETURNS

The theory of production in economics consists of an analysis of how entrepreneurs, under a given "state of art" or technology, combine various inputs to produce a stipulated output in an efficient manner. The core of production theory relevant to efficient resource allocation is based on the concept of the production function and the law of diminishing returns. A production function in general is an expression of the relationship between the physical inputs and output.

The law of diminishing marginal returns is actually an empirical assertion of reality and it states that as the amount of a variable input is increased, with other inputs held constant, a point is reached beyond which the marginal product declines. This law is valid under the following conditions: (a) the state of technology is given, (b) the possibility exists for varying a single input, (c) there exist other productive services whose quantities can be held constant.

A Production function of the classical type includes ranges of increasing, decreasing and negative marginal returns. In terms of the total product curve these ranges help define the three stages of production, illustrated with respect to a single variable input in the following diagram:

output (Y)

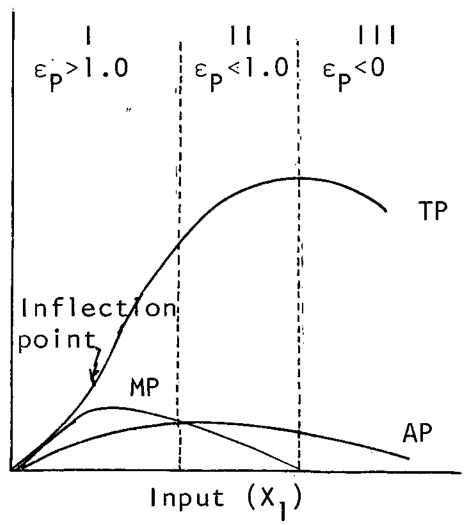

Figure 3.1. Stages of Production and Rational Resource Use

Any level of resource utilization in Stage I of production is clearly uneconomic since increasing average returns to the variable input are associated with under utilized fixed inputs. A rational producer would never operate in this region, since application of additional variable inputs could always bring about higher average productivity. In this stage, the fixed inputs are present in too large a proportion relative to the variable input. Therefore, a greater product from given resources could be attained by discarding or leaving idle some of the fixed factors. However, in the extreme short-run, it may be necessary for the producer to operate in stage I if there is no possibility of applying more variable input or allowing some of the fixed inputs to remain idle. It must be remembered that as the length of run under consideration increases, more and more of the fixed factors become variable until in the extreme long run all factors can be said to be variable.

Stage III covers the other area of irrational production. Here, the marginal product of the variable input is negative implying a declining total product. In stage III the resource input is combined with fixed inputs in uneconomically large proportions and the variable input is used beyond the point of zero marginal product. Under these circumstances, withdrawal of some of the variable inputs will always lead to an increase in total output. It is theoretically possible for farmers to operate in such regions due to lack of information and resource adjustment problems. Nonetheless, instances of it happening are likely to be isolated and rare.

Thus, under conditions of rational decision making stages I and III are eliminated from a production process. Production must occur in stage II--between the extensive and intensive productivity margins of the variable input. In other words, production must take place within the range of variable input application which runs from maximum average product to zero marginal product. Therefore the level at which a variable input is applied to fixed factors can never fall outside this stage if the goal is to maximize profit. However, this condition determines only a range of economic operation. Stipulation of the exact point of optimal resource allocation would involve consideration of prices of input and output. This development is discussed in the following section.

A-2. CRITERIA FOR EFFICIENT RESOURCE ALLOCATION

If total profit whether for the agricultural industry as a whole or for a farm, is to be maximized, resources must be allocated among different technical units in such a manner that their marginal value productivities per rupee of inputs are equal in all cases. Maximum allocative efficiency is obtained only when it becomes impossible to reallocate resources without decreasing total product.

In order to ascertain profit maximizing proportions and amounts of resources to use in production, it is necessary to apply the concepts of marginal factor cost (MFC) and marginal value product (MVP). Marginal factor cost refers to the cost of acquiring a unit of an additional input while MVP refers to the additional gross income resulting from a unit increase in the input, ceteris paribus. As will be shown later in this chapter, the criteria for determining efficient resource use are based on marginal values alone.

In a situation where one variable resource and one output are involved, the optimum utilization of the resource is achieved when its marginal value productivity equals its cost. Mathematically if the production function is represented by,

$$Y = f\,(X_1 \mid X_2 \text{ -- } X_n) \text{ where } X_2 \text{ --- } X_n \text{ are fixed}$$

then the marginal product (MP_1) is given by,

$$MP_1 = \frac{\partial f(X)}{\partial X_1} \qquad [3.1]$$

Denoting the prices of output and input by P_y and P_{X_1}, it can be seen that the first order condition for maximizing the profit function,

$$\Pi = \text{Max} \quad P_y.Y - P_{x_1}.X_1$$

is given by,

$$P_y \cdot \frac{\partial f(X)}{\partial X_1} = P_{X_1} \qquad [3.2]$$

and therefore,

$$P_y = \frac{P_{X_1}.\partial X_1}{\partial y} \qquad [3.3]$$

Equation [3.2] shows that the value of the marginal product of the input is equal to its price and equation [3.3] indicates that product price equals marginal cost, at the profit maximizing level of resource allocation. In the same manner, when several variable resources are being considered, the function can be represented as,

$$y = f\ (X_1,\ X_2,\ X_3\ \ldots\ldots\ X_n) \qquad [3.4]$$

and

$$MP_i = \frac{\partial f(X)}{\partial X_i},\ i = (1,2,\ldots n) \qquad [3.4]$$

The optimal combination of inputs occurs when the following first order conditions hold for all inputs X_i,

$$P_y \cdot f_1\ (X) = PX_1 \qquad [3.5]$$

$$\vdots$$

$$P_y \cdot f_n\ (X) = PX_n$$

from which it follows that,

$$\frac{P_y \cdot f_1 (X)}{PX_1} = \frac{P_y f_2 (X)}{PX_2} = \ldots = \frac{P_y f_n (X)}{PX_n} = 1 \qquad [3.6]$$

The above equations show that the necessary condition for profit maximization stipulates that the ratio of marginal value product to marginal factor cost must be equal to one for all variable resources. However, in situations of capital constraint, it will not be possible to utilize production inputs up to the point where MVP's equal MFC's. Hence under this condition ratios in equation [3.6] will be greater than unity for profit maximization. Consequently, for maximum economic efficiency to exist in a limited capital situation, resources must be allocated in such a manner that corresponding MVP's and MFC's show only the same ratios. If capital is unlimited the ratios must be equal to unity to achieve profit maximization.

The analysis so far is based on assumptions that farmers are profit maximizers, the levels of certain input factors are variable and the risk and uncertainties involved in production and marketing are minimal. It is sometimes necessary to relax these assumptions.

Incorporating risk and uncertainty considerations for resolving questions of profit maximizing behaviour in peasant farming, requires complex methods which are beyond the scope of this thesis. The control of factor inputs by farmers is of direct interest when dealing with resource allocation on the farms in the present study. Observed levels of application of most inputs, although varying, do not cover very wide ranges due to factors such as capital constraints. Therefore, a few comments on the implications of control of factor inputs by farmers are desirable.

Usually, certain factors of production in farming cannot be increased in the short run. This is particularly true in the case of land. However these factors can be decreased easily by non-use. For example labour, which is supposedly in excessive supply in developing economies, could be reduced if it did not earn its marginal factor cost. Any labour regarded as free, e.g., family labour, could be employed up to zero marginal productivity without reduction being necessary.

The existence of inputs which cannot be increased in the short run, can create conditions of constrained profit maximization. This situation can be formulated in mathematical terms as follows. Assuming P_y to be the price of output and P_i and P_j to be the price of factors X_i and X_j, respectively, then firm's revenue function is given as:

$$T.R. = P_y \cdot f(X_i, X_j) \qquad [3.7]$$

and its total cost as,

$$T.C. = P_i X_i + P_j X_j \qquad [3.8]$$

Therefore, profit Π is given by:

$$\Pi = P_y f(X_i, X_j) - P_i X_i - P_j X_j$$

and from the first order conditions for a maximum we get,

$$P_y f_i - P_i = 0 \qquad [3.9]$$

$$P_y f_j - P_j = 0 \qquad [3.10]$$

From equations [3.9] and [3.10][1] it is seen that at optimal levels the factor price ratios should equal the marginal rates of substitution when the two resources are variable. However, in the case considered the optimum level of X_j cannot be achieved because of its constrained nature. Therefore, instead of [3.10] the following condition holds.

$$P_y \cdot f_j > P_j \qquad [3.11]$$

Therefore equations [3.9] and [3.11] give the condition,

$$\frac{P_j}{f_j} < \frac{P_i}{f_i} \qquad [3.12]$$

or in terms of the marginal rate of substitution,

$$\frac{\partial X_j}{\partial X_i} = \frac{f_i}{f_j} < \frac{P_i}{P_j} \qquad [3.13]$$

or

$$\frac{f_i}{P_i} < \frac{f_j}{P_j} \qquad [3.14]$$

This illustrates that when a factor is limited below the level required for unconstrained profit maximization, the marginal conditions (or constrained profit maximization) easily fit in with the theory

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[1] f_i and f_j refer to first derivatives (marginal productivities) with respect to X_i and X_j. In stating equations [3.9] and [3.10] it is assumed that second order conditions are satisfied.

previously explained. Thus the farmer will only maximize in so far as he can adjust variable factors under the principle of equi-marginal returns. Since paddy farmers are often constrained by cash resources and other rigidities, they find themselves frequently trying to maximize profit in the short-run under sub-optimal conditions.

a. Necessary Conditions

Heady[2] points out that certain necessary conditions must be met before maximum efficiency of farm resources can be attained. He states them as follows:

1. The marginal rate at which factor is transformed into product must be the same for any pair of farms using the same factors and producing the same product.

2. The marginal rate of substitution between any pair of factors must be the same for any two farms using both to produce the same product.[3]

3. The marginal rate of substitution between two factors must be the same for every product in which they are used.

4. The marginal rate of substitution between any two products must be the same for any two farms producing both.[4]

5. The marginal rate at which two crops substitute as products on one farm must be equal to the marginal rate at which they substitute as factors on another (or the same) farm.

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[2] E. O. Heady, Economics of Agricultural Production and Resource Use, New York, Prentice-Hall, Inc., 1952, pp. 708-710. Two other conditions are defined besides those quoted. These concern income and utility of a resource in production and consumption as well as an adaptation of conditions previously stated.

[3] For detailed discussion of the factor-factor relationship and the factor substitution relationship see Ibid., Chs. 5, 6, and 7.

[4] For discussion of the product-product relationship see Ibid., Ch. 7.

6. Price ratios must equal substitution and transformation rates in all cases such that (2) the factor-product price ratio equals the marginal rate at which the factor is transformed into product, (b) the product-product price ratio is equal to the marginal rate of substitution of any two commodities, (c) the factor-factor price ratio is equal to the marginal rate of substitution between any pair of factors, (d) the discounted price ratio is equal to the substitution ratio for one product produced at two points in time, and (e) the compounded price ratio is equal to the substitution ratio for two resources extending into time.

b. Sufficient Conditions

The propositions enunciated above indicate the economic and technical production conditions which are necessary for (a) maximization of output from given resources or (b) minimization of resource inputs to produce a given level of output.

Taken by themselves these conditions do not guarantee the most efficient resource allocation. Sufficient conditions for optimal resource allocation require that products are produced under decreasing returns (increasing costs). They also stipulate that resources substitute at decreasing rates and commodities in combination are produced within the complementing and supplementary ranges of opportunity curves.

c. Relevance of Average and Marginal Productivity Estimates

It can be shown that estimates of marginal productivity serve better than those for average productivity as a basis for making national resource adjustment. The only instance where average productivity of resources can be used as a reliable basis for resource allocation, without reference to marginal productivity, is in the extremely simplified case where the production function is homogeneous of degree one (i.e., constant returns to scale) involving only one input variable. When this condition holds, marginal productivity of a resource is constant and is equal to average productivity at all levels of resource use. In homogeneous functions of degree one with more than one independent variable, marginal and average value products do not coincide. However, even though there may be only one input variable, if the production function includes both increasing and decreasing marginal returns, as is the case in the classical production function, average productivity estimates do not serve as a useful criteria of efficient allocation.

B. SELECTION AND APPROPRIATENESS OF METHODOLOGY

Recent developments in quantitative research in the microeconomics of farm production are characterized by a variety of mathematical research models. The techniques for investigating economic adjustment possibilities of farm production are numerous and they can be classified under three broad categories, namely:

1. budgeting
2. programming techniques
3. functional analysis

Budgeting has been a traditional method of estimating gains and losses in farm management studies. A farm budget can be defined as a set of expectations for resource use of the farm. A plan projected for the entire mix of products and inputs, including marketing and financing, is described as a complete budget, while a plan involving only part of the production process is referred to as a partial budget. In a partial budget a small change is made in the quantity and kind of resources used, and the gain or less in net revenue is estimated. A capital budget is frequently used when dealing with allocation of farm capital with or without intertemporal specifications. It is in fact another form of partial budget.

Programming models have been widely used in agriculture for the past two decades. These serve as important management and policy tools for the analysis of individual or aggregate farms, regional production patterns and interregional competition. The most common programming technique is linear programming.[5] This technique involves optimization of an objective function subject to a set of linear resource constraints. The major underlying assumptions are: linear production technology, additivity of activities and divisibility of products and resources. A number of other programming techniques such as quadratic integer and mixed integer programming also exist, but their use is not widespread due to complexities in application. Quadratic programming involves a non-linear objective function while integer programming attempts to solve a problem with all integer variables. In the mixed integer programming technique only selected variables need to satisfy the integer requirement.

Budgeting and linear programming are fundamentally similar techniques used for guiding the allocation of resources. The difference between them lies in the number of activities that can be handled and the

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[5] For a detailed account of linear programming technique see E.O. Heady and W. Candler, Linear Programming Methods, Ames, Iowa State College Press, 1958.

method of solving the production problems. Although budgeting is commonly used in simple planning problems, it finds limited application to situations with a large number of resource constraints and activities. Another advantage of linear programming over budgeting is that it compels the researcher to explicitly state the value judgements and production relationship that are assumed to hold good in the model itself. Linear programming has another advantage in that it can be used as a procedure for providing normative solutions to fundamental problems. By normative we refer to the course of action which ought to be taken by an individual or economic unit (a) when its objective takes a particular form and (b) the restraint conditions surrounding the action or choice are of a particular form.

Generally speaking, linear programming is not a tool for positive analysis. In contrast to normative, the term positive describes analysis which explains phenomena as they exist and not as they ought to be. For example, linear programming might be used to derive a normative supply function for farmers which would indicate the amounts which should be produced at different prices, if farmers had perfect knowledge and actually maximized profits. On the other hand regression analysis can be used to derive a positive supply function. This would describe or predict how farmers actually respond to price changes and would probably differ from the normative supply function. Linear programming and budgeting are not techniques for estimating production functions by themselves; instead they represent methods of determining production values based on given input-output relationships. In essence they are planning techniques which provide a method of systematically analyzing a production situation.

Functional analysis based on regression methodology, is used in the present study. As with any other analytical tool, functional analysis also has its limitations. However, it has certain characteristics that make it appropriate for studying the efficiency of resource use and possible adjustments. These are stated below:

1. Productivity coefficients of inputs can be readily estimated directly from data used in analysis.
2. Effects of different levels of input categories can be measured by this method. Marginal value productivity estimates for different levels of inputs show such information because the contribution in production of any level of a single input is contingent upon the level at which other inputs are employed.
3. Functional analysis is appropriate for handling adjustment possibilities within an existing technology because it permits estimates to be made of resource marginal productivities. These are calculated from the production function which is estimated directly in the analysis. Actually, specific commodity production function analysis usually assumes that the same basic technology is used by all farms, but at different input levels.

CHAPTER IV

CONCEPTUAL MODEL AND DATA

The first section in this chapter deals with the nature of rice production from an operations standpoint. The second section is concerned with the formulation of a conceptual model of production. The third section deals with the categorization and measurement of explanatory variables. The last section discusses the procedure for collecting data from farmers.

A. TECHNIQUE OF PADDY PRODUCTION

Rice production is a complex and varied phenomenon in Sri Lanka. Complexity arises out of the numerous steps involved, various kinds of inputs required, timing of inputs, different varieties of rice adaptable to different environmental conditions, and regional variability in cultural practices.

Land preparation is a critical operation in paddy cultivation. At the beginning of the season land is prepared thoroughly to make it suitable for sowing seeds or for transplanting seedlings. Land preparation is done by manual labour, buffaloes or tractors. Seed sowing and transplanting are performed exclusively by manual labour. Transplanting is considered to be a management practice requiring relatively large amounts of labour. Once the establishment of the rice stand is completed, the range of pre-harvest operations includes weed and pest control, irrigation and application of fertilizers. Harvesting is usually carried out three to four months after establishment of the crop. It is done by manual labour alone. The harvested crop is threshed to the final product, paddy, and this operation is performed by manual labour, buffaloes and tractors. Paddy farming in general involves a labour intensive system of production. The usual labour requirement for farming an acre of paddy ranges from about 55 to 90 man days. Instances where some farmers use more labour units than others can usually be explained by the fact that they employ more labour intensive practices such as transplanting and hand weeding. In addition to manual labour, most farmers use tractors or buffaloes for land preparation and threshing operations. It is a fact that high yields of paddy can be obtained by using non-traditional inputs, particularly fertilizer.

B. CONCEPTUAL MODEL OF PADDY PRODUCTION

On the basis of this description of paddy farming operations, it is possible to hypothesize the general form of the paddy production function as follows;

$$Y = f\ (X_1, X_2, X_3, X_4, X_5, X_6, X_7, S) \qquad [4.1]$$

where, Y is the total output, X_1 is land, X_2 is labour, X_3 is fertilizer, X_4 is agro-chemicals, X_5 is tractor services, X_6 is buffalo services, X_7 is seed material and S represents a random variable, consisting of a whole array of influences such as climatic, geographical, social and political factors, which is exceedingly difficult to measure in entirety. Even when it is not measured, as is frequently the case, regression analysis still permits statistical estimates to be made of Y through the assumption of normally distributed mean-zero error terms around the line of regression. When S is omitted under factor shares estimates the assumption is again the same with regard to the statistical model.

C. INPUT AND OUTPUT VARIABLES

The concepts, definitions and major difficulties connected with the selection and measurement of variables included in the analysis, will be discussed in the following section. All value measures referred to are in 1973 rupees.[1]

Output

The independent variable used in the study was the value measures of total rice output on farms in the 1972-73 Maha season. The output data obtained from the individual farm units were in physical units, namely bushels of paddy, which included total domestic consumption, sales and payments in kind for rents and wages. The value of output was obtained by pricing the physical output at the government guaranteed price, which at the time of survey was Rs.16.00 a bushel.

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[1] One Rupee was equivalent to .1506 Canadian Dollars at the official exchange rate in 1973.

[2] One bushel of paddy is equal to 45 lbs.

A price of Rs.16.00 a bushel was used in valuing the output of all farms for two main reasons. Firstly, most of the farmers were in fact subsistence oriented, so that very little or no marketable rice surplus is produced. Secondly, in Sri Lanka, the scheme of paddy purchasing implemented by the government stipulates that there will be no paddy sales by producers to outside sources other than the Paddy Marketing Board. The use of an unique price level might be objected to on the grounds that it disregards quality differences in the product. However, an examination of the varieties of rice grown by the sample of farmers revealed that there were no appreciable quality differences, which fortunately makes the application of production function analysis straightforward from the dependent variable standpoint. Almost all the farmers in the sample grew high yielding varieties of rice which did not show marked differences in quality and hence, one can expect the government price to be closely representative of the homogeneous output. This of course would not be the case if traditional varieties were being cultivated.

Land

The measure of land input used in the analysis is in terms of farm area under paddy cultivation. An alternative and perhaps better suited measure of land input would be the value of land under rice production. But in this case the assumption that the productivity of land is implied by its price is cruicial, and it has to be remembered that apart from the productivity consideration, the price of land can be affected by a number of other factors. If any of these apply, then value of land becomes that much less satisfactory as a measure. Furthermore, in rural areas there does not exist an active market for paddy land and this again leads to difficulties in assessing land values. In view of these considerations it was decided to use the physical area as the most satisfactory measure of land input available.

Labour

Labour input was expressed in terms of man-days, where a period of eight hours of work was considered to be a man-day. This involved measurement of total labour input used directly for production of paddy, excluding that used for driving tractors and buffaloes.

The entire system of labour utilization in paddy cultivation is relatively complex. Three categories of labour--men, women and children--are used. Labour commitment is highly seasonal in nature and during certain critical phases of requirements, such as planting, harvesting and threshing, the family labour supply is often inadequate, and therefore has to be augmented by hired or exchange labour (attan). In general, rice farming is not a system of farming which can make do on the supply of family labour alone. In fact, it has been shown that the share of hired labour in total labour requirements is as high as 85 per cent in certain districts.[3]

In view of the different categories of labour employed in rice cultivation, it was necessary to bring all labour into an appropriately

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[3] K. Izumi and A.S. Ranatunga, Cost of Production of Paddy Yala, 1972; Agrarian Research and Training Institute, Sri Lanka, Research publication No. 1, July, 1973.

equivalent form. This was accomplished by converting woman and child labour days to man-day equivalents, using the following index of conversion: one woman-day and one child-day equivalent to .75 and .5 man-days respectively. These indices[4] of conversion were based on the average wage rates prevailing at the time of survey. It is assumed that the average wage rates of the categories of labour adequately reflect their different productivities.

Fertilizer

The fertilizer variable was defined as the total value of fertilizers used in producing rice output on a farm. The prices are those at which fertilizers were purchased by the farmers after a government subsidy of 50 per cent of total cost had been deducted. Generally speaking farmers were observed to keep the combination of fertilizer ingredients reasonably constant. This allowed total value to act as the variable measure.

Chemicals

A number of chemicals are used in rice cultivation. These take the form of various seed dressings, herbicides and insecticides. Owing to the heterogeneous nature of individual chemicals, an aggregate value of chemicals used on each farm was obtained for measuring the corresponding variable.

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[4] For a similar situation in India, Chenareddy uses the following indices: one woman-day equivalent to .8 man-day and one child-day equivalent to .5 man-day. See: V. Chenereddy, "Production Efficiency in South Indian Agriculture," J. Farm Econ. 49, 1967, pp. 816-20.

Buffalo Services

This variable represents animal power utilized for ploughing land prior to plant establishment and threshing the harvest. Measurement was made in value terms and includes the expense of hiring buffaloes as well as their attending labour. Usually, a buffalo service unit used in rice farming consists of two animals and the attending buffalo driver. The typical approach to measuring this variable has been to assess the buffalo service independently from attending labour. However, it seems logical to consider the services of both buffalo and driver as a single unit, each complementing the other.

Machinery Services

Machine power represents a major input in rice production and is used for field preparation and for threshing. The types of machines used are either "two wheel" or "four wheel" tractors. As in the case of animal services, the measure of machinery input includes the cost of hiring both tractors and drivers. Even though tractor usage is fairly common among the paddy cultivators, a majority of farmers do not own them. In instances where farmers used their own tractors computation of the costs of tractor inputs was based on the normal tractor hiring charges prevailing in the area. The cost of using production equipment is also incorporated in the machinery services variable. Apart from tractor-cultivator attachments, equipment items are infrequently used by sample farmers and when present might comprise spraying machines, rotary weeders and water pumps. A hiring equivalent cost was charged for these items which excluded labour.

Seed Material

The measure for this variable involved a value assessment of the seed paddy used on each farm, at Rs.18.00 per bushel.

Draft Services

This variable is a summation of Machinery services' and animal services' variables outlined above.

Regional Dummy Variable

Regional factors can influence levels of production and therefore the production function. It was thought useful to define a zero-one dummy variable for the purpose of indicating the presence of regional effects in one part of the analysis.

D. SOURCE AND METHOD OF COLLECTION OF DATA

The present study is based on input-output data previously collected from 107 rice farms in five major rice cultivating districts in Sri Lanka, namely: Polonnaruwa, Hambantota, Kurunegala, Colombo and Kandy.[5] The time period referred to in this study is the 1972-73 Maha season. Maha or wet season, extending from September to March, is the major rice growing season in Sri Lanka.

The method employed for collecting data was that of supervised farm record keeping. The usual approach for gathering farm data in rural areas in developing countries has been the field survey, where a

[5] The district sample breakdown of farm numbers is given in Appendix 6.

once-and-for-all interview is conducted by a trained enumerator using an appropriately designed interview schedule. However, this technique seemed to be clearly unsatisfactory for collecting information in view of the errors that could creep into the data. In a farm situation where rice production extends for a period of 4-5 months, and where no record of the farming enterprise is maintained at all, the recall lapses of a farmer can be substantial and seriously affect the accuracy of information obtained. Since rural farmers are not used in maintaining production records by themselves, a supervised record keeping method had to be adopted. This involved systematic maintenance of records by farmers with the assistance of agricultural extension personnel, who supervised them at regular intervals, particularly during the peak periods of farming.

Selection of the farm sample in this study was made on a judgement basis and all the farmers included in the sample had the rice crop as their major source of income. On the basis of local experience it was thought that farm units included in the sample represented a typical cross-section of rice farming in the areas under study. Therefore, despite the fact that the original sample was not chosen under a random selection procedure, the data representation was considered to be adequate for estimating valid functional relationships between inputs and output. Hence it should be made clear that although the sample was not taken at the time with the express purpose of performing functional analysis, the fundamental input-output data which it was meant to provide also ensured its relevancy for production function estimation.

Heady[6] has pointed out that although a random sample is most suitable for deriving population parameters it is often clearly unsatisfactory for estimating regression coefficients. He proposed that estimation of regression coefficients be based on an equal distribution of variable observations through the entire range of study data. Thus we see that data for regression analysis should be representatively scattered with respect to the plane or surface relationship being estimated. The use of sample data from a group of record keeping farmers may perhaps lead to some difficulties in regression estimation. For instance, a paddy farmer who is keeping records might be expected to operate a more efficient and better adjusted farm. If this were true the inputs from such farms would tend to cluster around scale lines, implying high intercorrelations among independent variables which would reduce the reliability of estimated regression coefficients.[7]

In order to avoid this problem Johnson[8] suggests that selection of farms be done on a purposive basis with two objectives in mind. Firstly, the intercorrelation between the input factors be kept as near to zero as possible and secondly, maximization of the variances be achieved in the

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[6] E.O. Heady, "Elementary Models in Production Economic Research," J. Farm Econ., 30: 1948, pp. 201-26.

[7] For a discussion of this subject see: H.S. Konjin, "Estimation of an Average Production Function from Surveys," Economic Record 35: 1959, pp. 118-25.

[8] E.O. Heady, Glen Johnson and Lowell S. Hardin, Resource Productivity, Returns to Scale and Farm Size, Iowa State College Press, Iowa, 1956, p. 95. In this reference Johnson also points out that random samples can suffer from lack of resource combination variability.

factor dimension without drawing observations in stage I or III, where, Cobb-Douglas functions would encounter certain interpretational difficulties. Therefore, in using the data for the study, the writer who was associated in its compilation in Sri Lanka, is satisfied that such sampling conditions were met to a reasonable degree. The data is thought to permit valid regression coefficient estimates.

CHAPTER V

ESTIMATION OF PADDY PRODUCTION FUNCTIONS AND INTERPRETATION OF RESULTS

Before saying anything about estimation procedures it is necessary to state the reason for dealing with the total farm sample first of all and then proceeding to the regional analysis, rather than the other way round. Early on it was thought that any analysis of the data collected should include both a total and regional farm sample approach. While there was prima facie evidence suggesting that the dry climate areas showed higher response to inputs in the Maha season, this position was sufficiently interesting for a comparison of the two approaches to be rendered necessary. With that decision taken it seems logical to proceed with the total farm sample analysis first, because it permits a focussing of attention from a broad context to narrower ones. In this way factor shares estimates can be applied and appraised without duplication, because it was omitted for the regional data.

In using the order of analysis indicated, having decided that the comprehensive approach was relevant, the author felt quite uncompromised as to making correct judgements on the basis of actual results.

This chapter then is divided into two major parts. Part A is concerned with the estimation of production functions and analysis of resource productivity for the overall sample of farmers selected for the study. Part B involves estimation of production functions and resource functions productivity analysis for regional farm samples within the main sample and productivity index comparisons between the districts composing the regions.

A. ANALYSIS OF THE TOTAL FARM SAMPLE

1. Estimation of Production Functions

A number of econometric techniques are available for estimating production functions and these can be categorized under four main headings. They are: (i) the factor shares method, (ii) the single equation least squares method, (iii) the covariance matrix method and (iv) the instrumental variables method. The first two methods receive application in the study and will be discussed at length. The covariance matrix and instrumental variables methods are not widely used, particularly on cross-section data, and will not be discussed further.[1]

a. Factor Shares Estimates

An attempt was made to derive the productivity coefficients of the production function for total sample data by use of a relatively simple method called "factor shares" which has been described by Klein.[2] This method in conjunction with least squares has been used by Mundlak[3] for deriving a production function from a combination

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[1] For a detailed discussion of these methods see Ronald J. Wonnacott and Thomas J. Wonnacott, Econometrics, London, John Wiley and Sons, Inc., 1969, pp. 237-383.

[2] Lawrence R. Klein, A Text Book of Econometrics, Evanston, Row Peterson, 1953, p. 206.

[3] Yair Mundlak, "Estimation of Production and Behavioral Functions from a Combination of Cross-section and Time Series Data," in Carl F. Christ, et al., Measurements in Economics, Stanford, California: Stanford University Press, 1963, pp. 163-165.

of cross-sectional and time-series data. Recently, Kislev[4] has estimated a production function for U.S. agriculture using the factor shares method.

(i) Technique of Estimating Production Coefficients by Factor Shares Method

Factor shares estimates are by far the simplest method of deriving structural coefficients of a Cobb-Douglas production function for a sector characterized by competition. The fundamental principle underlying this method can be illustrated as follows: Given a function of the form,

$$Y = a_o \prod_{i=1}^{n} X_i^{bi} \qquad [5.1]$$

then under competitive equilibrium, the marginal value product of the ith input will be equal to its market price or market earning rate W_i. If Y in equation [5.1] is expressed in terms of value of output, then for each input i,

$$\frac{\partial Y}{\partial X_i} = W_i \qquad [5.2]$$

In the Cobb-Douglas function the output elasticity of the ith resource is given by,

$$\varepsilon_i = \frac{\partial Y}{\partial X_i} \frac{X_i}{Y} \qquad [5.3]$$

Substituting equation [5.2] in [5.3] we obtain,

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4 Yoav Kislev, Estimating a Production Function from 1959 U.S. Census of Agriculture Data, Unpublished Ph.D. Thesis, University of Chicago, 1965.

$$\varepsilon_i = \frac{W_i X_i}{Y} \qquad [5.4]$$

where, $\frac{W_i X_i}{Y}$ represents the share of the outlay on the ith factor as a proportion of total output, which is equal to the factor's coefficient in the Cobb-Douglas production function [5.1].

A major assumption in the factor shares estimates method is the existence of a competitive equilibrium. Therefore, the use of this method in the present analysis raises the important question as to whether the paddy sector in Sri Lanka was in equilibrium during the period of study, and if it was, whether it achieved this under competitive conditions. The concept of equilibrium can be treated from short-run and long-run standpoints. Within the last ten years the paddy producing sector has witnessed significant changes with respect to technological, economic and social factors. Owing to these changes and relatively slow dissemination of information to farmers, it is quite possible that the short-run observation data used in the study will not represent a long-run equilibrium position. One way of attempting to overcome such a problem would be to average observations over a long period of time. That was not possible in the study, so proceeding on the assumption that short-run equilibrium conditions in paddy farming existed, it is useful to establish just how much competition was present in the factor and product markets to allow competitive equilibrium to apply.

Another major criticism of the factor shares technique is that it does not allow much scope for testing hypotheses about economies of scale. If the method is used to estimate the coefficients of all factors of production, their sum should be unity implying the assumption of constant returns to scale. On the other hand, if the industry being studied is characterized closely by perfect competition, then, there will be no necessity for testing the presence of increasing or decreasing returns to scale. In this case, the factor shares method will give the most satisfactory estimates of production coefficients.

Despite these limitations the use of factor shares estimates for deriving production coefficients provides some advantage. For instance, the production coefficient estimated by this method for a particular input, unlike that obtained from least squares, is independently determined from those for the other factors of production. Hence, an error in estimating a particular production coefficient by the factor shares method will not cause errors in estimating other coefficients. Nevertheless, factor shares estimates are influenced by the prices of inputs and output and, therefore, any error in determining these can cause errors in the coefficients obtained.

Factor shares estimates can be made for different resource and output combination levels. For the sake of representation in the study, they were estimated at the arithmetic and geometric mean combinations for the total farm sample.

A distinct advantage of the factor shares method as suggested by Mundlak[5] is that it can be used along with the least squares method for estimating production function coefficients free of simultaneity bias. According to his suggestion the coefficients of inputs which are found to be correlated with observed output data are estimated by the factor shares method. The remaining coefficients are derived from regression in which factor shares determined coefficients of variables are also imposed. For the data in the present study it was not evident that use of this composite technique would result in better estimation procedure, and so it was not applied.

(ii) Models Used in Factor Shares Estimation

The statistical models used in Factor Shares Estimation are as follows:

(a) at the arithmetic mean levels of inputs and output,

$$S_i = a_i + u_i \quad (i = 1.....n) \qquad [5.5]$$

where S_i is the share of ith input, a_i is the production elasticity coefficient of the ith input and u_i is the random error term.

Assuming the mean of u_i to be zero, then

$$\hat{a}_i = \bar{S}_i$$

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[5] Yair Mundlak, "Estimation of Production and Behavioral Functions from a Combination of Cross-section and Time Series Data" in Carl F. Christ et al., Measurements in Economics, Stanford; California, Stanford University Press, 1963, pp. 163-165.

(b) Similarly, at the geometric mean levels of inputs and output, using the same notation,

$$S_i = a_i e^{u_i} \quad [5.6]$$

Hence,

$$\ell\eta\, S_i = \ell\eta\, a_i + u_i$$

Again the u_i are assumed to have a mean of zero

Therefore,

$$\ell\eta\, \hat{a}_i = \overline{\ell\eta\, S_i}$$

and

$$\hat{a}_i = \text{antilog}\, (\hat{\ell\eta}\, a_i)$$

It has been shown that coefficients determined under factor shares in model (b) unlike those in model (a), are subject to bias arising from the logarithmic transformation involved.[6] The relative bias in model (b) is given by the term,

$$\frac{\sigma_r^2}{2n} \quad [5.7]$$

where, σ_r^2 is the variance of the coefficient b_r and n is the sample size. From the above expression it is clear that smaller samples will have greater bias of this nature. However, with a total farm sample size

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[6] P. J. Dhrymes, "On Devising Unbiased Estimator for the Parameters of the Cobb-Douglas Production Function," Econometrica, 31, January-April 1963, p. 297.

of 107, it can be observed that coefficient estimates will not be biased substantially, even if model (b) is used.

After considering all these factors it can be concluded that the factor shares estimates method of deriving production functions is a valuable analytical tool, insofar as it provides an opportunity to compare its results, under competitive equilibrium assumptions, with those derived from least squares regression.

(iii) Empirical Results of Factor Shares Estimation Model

The computed factor shares estimates for the overall sample along with corresponding mean values of output and inputs are reported in Table 5.1. The figures indicated in column (3) are geometric means while those in column (5) are arithmetic means. It is seen that corresponding arithmetic means and geometric means differ from one another. These differences are a function of the skewness of distributions. Columns (4) and (6) indicate the factor shares estimates computed at geometric and arithmetic input levels, respectively. In spite of the marked differences observed in the inputs at the geometric and arithmetic mean levels, the associated factor shares estimates do not show substantial differences. However, it is more appropriate to concentrate on the production coefficients with regard to geometric means because these are closer to the "typical" farm situation.

The mean values given for the draft power variable, X_8, represent an aggregation of both animal and machine power variables. These variables were treated together here because they were subsequently handled this way in regression analysis.

Table 5.1. Factor Shares Estimates of Coefficients of Farm Based Cobb-Douglas Production Function at Geometric and Arithmetic Mean Levels of Output and Inputs for the Maha Paddy Season (6 months)

Farm Variable[1] (1)		Value Units (2)	Farm Geometric Mean Value (3)	Factor Share (4)	Farm Arithmetic Mean Value (5)	Factor Share (6)
Y	Output	Rupees Rs.	1638.00	1.000	2442.00	1.000
X_{1a}	Land[2] (a)	Rs.	409.50	0.250	540.00	0.221
X_{1b}	Land[2] (b)	Rs.	486.00	0.297	673.00	0.276
X_2	Labour	Rs.	634.40	0.387	835.70	0.342
X_4	Fertilizer	Rs.	80.50	0.049	136.00	0.056
X_6	Agro-chemicals	Rs.	32.00	0.019	46.00	0.019
X_7	Seed Material	Rs.	55.40	0.034	62.60	0.026
X_8	Draft Services	Rs.	199.00	0.121	334.00	0.137
	Sum of Factor Shares					
	(a)		-	0.860	-	0.801
	(b)		-	0.907	-	0.856

[1] Variables are defined in Chapter IV.

[2] Value of land was calculated using two different approaches:
(a) average rent payment was capitalized to give the total value of land,
(b) paddy land was valued at Rs.3000 per acre.
For the purpose of estimating the factor share to land, it was necessary to apply a 9 per cent semi-annual interest rate to each farm's land investment value. Therefore the geometric and arithmetic mean totals for variables X_{1a} and X_{1b} indicate the appropriate semi-annual opportunity costs on the respective land investment variables.

The factor shares estimate at the geometric mean for the draft service variable, X_8, is .121. The labour variable, X_2, shows the highest factor share estimate of .387. The lowest coefficient estimate is .019 which applies to agro-chemicals. The fertilizer variable, also shows a rather low estimate of .049. The small factor shares estimates for the two most important non-traditional inputs, fertilizer and agro-chemicals, seem rather puzzling at first. But the reason is almost certainly caused by prices which underestimate marginal value productivities. Two alternative factor share estimates for land were computed. The first was based on the average value of land rental payments while the second was based on the average assessed land value. In the latter case the average land value was set at Rs.3000.00 per acre. If we assume that these two value bases represent high and low assessments, then the corresponding factor shares estimates of .250 and .297 can be taken as upper and lower limits of the true coefficient for the land variable.

The sums of the factor shares estimates for the two alternative geometric mean level production functions, (a) and (b), are .860 and .907 respectively. These are not greatly divergent from 1, and while they suggest that a competitive equilibrium situation was not completely achieved, they do come close enough, assuming small data measurement error, for us to expect that paddy farmers' use of resources is influenced by competitive forces. Also the factor shares estimates provide a useful alternative basis from which to compare regression coefficient estimates.

b. Least Squares Estimates

The usual approach to estimating a production function is by regressing the output, or some monotonic transformation of output, on a set of appropriate input variables. The estimation in this study is limited to single equation procedure. This is based on the assumption that inputs are independently, and not simultaneously, determined. These conditions probably apply better to inputs whose levels are decided early in the process of production. Inputs applied at a later stage, such as harvest labour, can be correlated with actual level of output. A situation where variables are related to one another by more than one equation cannot usually be treated satisfactorily by single equation regression. Marschak and Andrew's[7] have shown that this type of problem connected with the estimation of production functions is similar to that faced in the estimation of supply and demand equations. A single equation model for the paddy production function can be justified on the basis that levels of most inputs are decided before the actual yield outcome is known. If this is the case, they can be said to be determined according to the expected level of output and, therefore will not be correlated with errors in the actual output. Under these conditions, single equation least squares estimates are not subject to bias caused by simultaneity relationships and this was the situation assumed in the analysis.

[7] Jacob Marschak and William H. Andrew, Jr., "Random Simultaneous Equations and the Theory of Production," Econometrica 12: July-Oct., 1944, pp. 143-205.

(i) Statistical Model of Paddy Production Function

Using the variables indicated in the conceptual model presented in Chapter IV we can now hypothesize the general form of the paddy production function for the ith farm,

$$Y_i = f\ (X_{1i},\ X_{2i},\ \ldots\ X_{7i},\ u_i)$$

where, Y_i is the output, X_i are the inputs and u_i is the random disturbance term, which is assumed to be normally distributed with mean zero.

In the linear from the function can be expressed as,

$$Y_i = a + b_1\ X_{1i} + b_2\ X_{2i} + \ldots\ b_7\ X_{7i} + u_i \qquad [5.8]$$

where a is the population constant term and b_i are the population production coefficients. Similarly, in the Cobb-Douglas form the equation can be written as,

$$Y_i = a\ X_{1i}^{b1}\ X_{2i}^{b2}\ \ldots\ X_{7i}^{b7}\ e^{u_i} \qquad [5.9]$$

Expressing equation [5.9] for each farm in logarithmic form we obtain,

$$\ell n\ Y_i = \ell n\ a + b_1\ \ell n\ X_{1i} + b_2\ \ell n\ X_{2i}\ \ldots\ b_7\ \ell n\ X_{7i} + u_i \qquad [5.10]$$

In order to estimate equation [5.10], the rationale and assumptions used by Zellner, Kmenta and Dreze[8] are adopted. These hold that the production functions of firms are identical in form and parameters. Therefore,

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[8] A. Zellner, J. Kmenta, and P. Dreze, "Specification and Estimation of Cobb-Douglas Production Function Models," Econometrica, 34: Oct. 1966, pp. 784-795.

in the logarithmic form the estimated production function for the sample is given as,

$$\ell\eta\ Y = \ell\eta\ a + b\ \ell\eta\ X_1 + b_2\ \ell\eta\ X_2 + \ldots + b_7\ \ell\eta\ X_7 \qquad [5.11]$$

where a, b_1 .... b_7 are coefficient estimates; or alternatively in the natural form as,

$$Y = a\ X_1^{b_1}\ X_2^{b_2}\ \ldots\ X_7^{b_7}$$

Similarly, in the linear form the estimated production function can be expressed as

$$Y = a + b_1\ X_1 + b_2\ X_2 + \ldots + b_7\ X_7$$

The simple correlation matrix for logarithmically transformed variables utilized in the analysis for all survey farms is presented in Table 5.2. This shows that all pairs of variables are positively correlated except in the case of animal services and machinery services. The reason for this negative correlation is the substitution of machinery services for animal services on farms.

The magnitudes of the coefficients in the correlation are useful for investigating the presence of collinearity[9] between independent variables. Generally, a high correlation between two independent variables

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[9] For an interesting discussion of this subject see: D.E. Farrar, and R.R. Glauber, "Multicollinearity in Regression Analysis: the Problem Revisited," Rev. of Econ. Stats., 49: 1967, pp. 92-107.

Table 5.2. Simple Correlation Coefficients[1] for Logarithmically Transformed Variables included in Paddy Regression Analysis--Total Farm Data--All Survey Farms.

Farm Variable[2]		Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Y Output	(Rs.)	1.00								
X_1 Land	(Acres)	.82	1.00							
X_2 Labour	(Man days)	.84	.69	1.00						
X_3 Fertilizer	(Rs.)	.88	.72	.32	1.00					
X_4 Machine Services	(Rs.)	.42	.77	.38	.74	1.00				
X_5 Animal Services	(Rs.)	.38	.27	.73	.78	-.83	1.00			
X_6 Agro-chemicals	(Rs.)	.59	.64	.63	.73	.10	.76	1.00		
X_7 Seed Material	(Rs.)	.84	.86	.81	.77	.18	.74	.67	1.00	
X_8 Draft Services	(Rs.)	.71	.71	.77	.78	.51	.70	.71	.62	1.00

[1] H_o: $\rho = 0$, rejected if calculated $r > .190$ (.05 L.O.S.)
$r > .248$ (.01 L.O.S.)

[2] For the definition of variables see Chapter IV.

is indicative of multicollinearity in regression estimation.[10] On *a priori* grounds it might be expected that some correlation would exist among variables in a productive process. The correlation matrix in

[10] The limitations of applicability of this criteria for detection of multicollinearity is discussed in P. Rao and R.L. Miller, *Applied Econometrics*, California, Wadsworth Publishing Co., 1971, pp. 46-52.

Table 5.2. indicates the presence of reasonably high and significant correlations among the explanatory variables. However, only in the cases of seed material and land (r=.86), animal services and machine services (r=-.83) and seed material and labour (r=.81) do the coefficients exceed .8. From research experience the size of the correlations between the independent variables indicates that while multicollinearity can occur among certain variables, it is not likely to be all that serious. Furthermore the forming of a composite variable from machinery and animal services can only serve to reduce whatever multicollinearity is introduced by the separate variables.

Some studies[11] have shown that the use of per acre data rather than total farm data tends to reduce correlations between the independent variables. This redefinition was attempted in the present study and the resulting correlation matrix did not show important differences from the correlation matrix in Table 5.2. In fact the correlation between labour and chemicals increased to (r=.89). Consequently, it was decided to use total farm data rather than per acre data, since the former had the benefit of being able to disclose information on returns to scale in paddy farming.

(ii) Estimation of Linear Production Functions

On the assumption that a linear production relationship existed between output and factors of production, two multi-linear regression equations were estimated using total farm data from all survey farms, and

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[11] Delane E. Welsch, "Response to Economic Incentive by Abakaliki Rice farms in Eastern Nigeria," Jour. Farm Econ., 47: 1965, pp. 900-914.

the results of these specifications are presented in Table 5.3.

The coefficient of multiple determination (R^2) for the two regressions show high values, .911 and .839, indicating that the functions explain a large part of the output variability. However, a statistical evaluation of the estimated coefficients reveals that the assumption of a linear production relationship for the population is not satisfactory. Regression R_1 incorporates all input factors employed in the conceptual model of paddy production, but the seed material, animal services and agro-chemicals variables show non-significant coefficients at the .05 level of significance (L.O.S.). The non-significance of the coefficients is due to the relatively low values of the coefficients in conjunction with their high standard errors. It is also important to note that the marginal productivity of agro-chemicals is shown to be negative in the first regression equation.

Therefore, in equation R_2 seed material and agro-chemicals variables were deleted and the model respecified to use a draft services variable in place of separate machine and animal service variables. The effect of these changes was to reduce the R^2 value slightly and to render the land and fertilizer regression coefficients non-significant at the .05 L.O.S. The constant terms for the two regression equations show statistically significant negative values. These may well indicate non-linear relationships underlying the data. In fact the general unsuitability of the linear production function in the natural form would also suggest that attention be directed towards a Cobb-Douglas type of function.

Table 5.3. Multi-linear Production Function Coefficients[1] --Total Farm Data--All Survey Farms

Regression		R_1	R_2
R^2		.911	.839
Y Total Output (Rs.)			
X_1 Land	(Acres)	296.227* (92.446)	96.049 (99.287)
X_2 Labour	(Man days)	8.331* (1.140)	10.603* (1.352)
X_3 Fertilizer	(Rs.)	2.141* (.811)	.598 (1.039)
X_4 Machinery services	(Rs.)	3.467* (.607)	-
X_5 Animal services	(Rs.)	.298 (.691)	-
X_6 Agro-chemicals	(Rs.)	-6.548 (5.856)	-
X_7 Seed material	(Rs.)	4.235 (3.089)	-
X_8 Draft services[2]	(Rs.)		3.104* (.597)
Constant Term		-206.665** (92.446)	-348.873* (101.560)

[1] Figures in parenthesis indicate standard errors.

[2] Composite of machinery and animal services.

* Significant at 1 per cent level

** Significant at 5 per cent level

$\therefore H_o: \beta=0$, rejected

(iii) Estimation of Non-linear Production Functions

Since the linearity assumption regarding the true production function was called in to question by the foregoing analysis, an attempt was made to fit a non-linear function to the total farm sample data. The most widely used non-linear function in agricultural production analysis is the Cobb-Douglas formulation. The more important reasons for selecting this specific form can be summarized as follows:

(i) Ease of computing production elasticity with respect to a particular input. Production elasticity of an input refers to the percentage change in output in response to a one per cent change in input;

(ii) It permits diminishing marginal returns to occur in the estimated function without using up too many degrees of freedom.

(iii) If the random error terms for the original data are small and normally distributed, log transformations of the variables will preserve normality of error terms in the redefined data. It should be noted that even if the error terms are not normally distributed, it is still possible to obtain best linear unbiased estimates by the application of the least squares method. However, in such a case statistical tests of significance are no longer valid.

The estimated Cobb-Douglas production function coefficients are presented in Table 5.4. The regression equations R_3 to R_6 indicate coefficients for progressively selected sets of variables. The seed variable

Table 5.4. Cobb-Douglas Production Function Coefficients[1] --Total Farm Data--All Survey Farms

Regression number		R_3	R_4	R_5	R_6
R^2		.953	.942	.933	.922
Y Total Output (Rs.)					
X_1 Land	(Acres)	.322* (.104)	.392* (.072)	.275* (.080)	.257* (.084)
X_2 Labour	(Man-days)	.569* (.084)	.564* (.079)	.594* (.083)	.599* (.082)
X_3 Fertilizer	(Rs.)	.243* (.037)	.231* (.022)	.223* (.034)	.203* (.035)
X_4 Machinery services	(Rs.)	.003 (.011)	.002 (.015)	-	-
X_5 Animal services	(Rs.)	.014 (.016)	.013 (.012)	-	-
X_6 Agro-chemicals	(Rs.)	-.044 (.034)	-.035 (.033)	-.049 (.030)	-
X_7 Seed material	(Rs.)	.087 (.094)	-	-	-
X_8 Draft services[2]	(Rs.)	-	-	.125** (.061)	.127** (.062)
Constant Term		25.028* (0.466)	33.685* (0.340)	19.068* (0.433)	17.219* (0.433)
Sum of elasticities		1.194	1.179	1.168	1.186

[1] Figures in parenthesis indicate standard errors (those for constant term refer to log-linear equation).

[2] Composite of machinery and animal services.

* Significant at .01 L.O.S.

** Significant at .05 L.O.S.

coefficient is again seen to be a non-significant in all the regressions. The machinery services and animal services coefficients are non-significant at the .05 L.O.S. The re-specification of these two variables in the form of a single draft services variable is seen to give significant coefficients in R_5 and R_6.

In equation R_3 the agro-chemicals coefficient is non-significant at the .05 L.O.S. and it also shows a negative production elasticity. Consequently, after retaining this variable in equations R_4 and R_5 and still not achieving any different result, it was dropped in the case of R_6. Thus R_6 leaves out agro-chemicals and seed material and includes the draft services input in place of machinery and animal services. In R_6 all regression coefficients prove significant at the .05 L.O.S. and a high R^2 value of .922 is obtained. Therefore, equation R_6 can be said to give a good fit to the observed output and input data using land, labour, fertilizer and draft services as independent variables.

As seen from Table 5.4 (p. 65) the regression equation R_6 differs from the conceptual model of production described earlier. The difference involves the exclusion of the agro-chemicals (X_6) and seed material (X_7) variables in R_6. On _a priori_ grounds one might expect these to be variables with significant coefficients. As regards seed material the reason for its exclusion may be explained by the fact that corresponding data variation in the farm sample was too small. On the other hand it is possible also that differences in seeding rates on farms were not systematically related to output.

Exclusion of agro-chemicals in R_6 may have resulted from a measurement problem. Farmers used a wide range of agro-chemicals. Therefore, the use of a value measure for this variable might have caused insufficient specification rendering it non-significant. It is also possible that the use of agro-chemicals by farmers in the sample showed insufficient variation or no systematic effect on yields, in which case the regression coefficient would be judged non-significant. The important fact, however, is that even after excluding seed material and agro-chemicals, the R_6 function explained 92 per cent of the variation in output, which is a good fit to the data.

At this stage we can compare the results of estimating production coefficients for the variable inputs by regression and factor shares methods. It is seen that the factor shares estimates for geometric mean input levels of land and draft services variables come reasonably close to corresponding regression coefficients in R_6. However, a difference between the results of the two methods exists regarding labour and fertilizer. The factor shares estimate for the labour coefficient is .387 while the corresponding R_6 regression coefficient estimate is .599. The factor shares estimated for the fertilizer coefficient is .049 and the corresponding regression estimate is .203.

The difference in the coefficient estimates from the two methods for both labour and fertilizer can be explained simply in terms of their marginal value productivities exceeding prices of the resources at geometric mean levels of application. This point will be expanded on later in the chapter.

2. Resource Productivity Analysis

As discussed above, the most satisfactory fit to the total farm sample data was given by production function R_6 in Table 5.4., which in the natural form is as follows:

$$Y = 17.2187\, X_1^{.2570}\, X_2^{.5987}\, X_3^{.2030}\, X_8^{.1272} \qquad [5.12]$$

This function is considered suitable for conducting resource productivity analysis at a total farm sample level. This is not to say that it constitutes an entirely satisfactory relationship for all the different areas covered by the total sample of farms. Nevertheless, pending refinement, it does seem to offer a very useful global function to work with in the absence of more suitable regional functions.

Based on this paddy production function a number of analytical criteria for identifying and evaluating the productivity of different resource inputs will now be dealt with. They are, returns to scale, pattern of resource use, average and marginal value productivities of inputs, contribution of each input to total product and the degree of allocative efficiency in overall production.

a. Returns to Scale on Paddy Farms

Returns to scale represent an important economic characteristic of a production process. They are defined as the proportional change in the dependent variable in response to a simultaneous and similar proportional change in all the inputs entering into production. If the input elasticities sum to greater than one, increasing returns to scale are indicated. If they sum to less than one it represents a situation of decreasing returns to scale. On the other hand if their sum equals one, then it implies constant returns to scale. In a Cobb-Douglas function returns to scale are indicated readily by its function coefficient (ε) which is obtained by summing the output elasticities (exponents) of the individual factors of production (see Appendix 2). The sum of the production elasticities for the included variables in equation R_6 is 1.186. This implies that a simultaneous change of one per cent in all inputs will lead to a 1.186 per cent change in the total output. Bearing in mind that the equation does not explicitly include all utilized inputs, especially management, as well as the fact that the coefficient is quite close to one, it is reasonable not to place too much emphasis on the indication that increasing returns to scale exists. Rather it is probably safer to think more in terms of constant returns to scale.[12]

b. Patterns of Resource Use on Paddy Farms

Before proceeding to a detailed analysis of productivities and efficiency in resource use, it is helpful to consider levels of input employed by the farmers. Accordingly the mean farm levels of input factors and output for the total sample are reported in Table 5.5. Comparison of the input and output geometric and arithmetic mean farm data reveals substantial differences between the two. In the case of land the average[13] farm acreage under paddy was 2.45 acres. The average

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[12] Null hypothesis that sum of elasticities (ε) equalled 1 was accepted at 1 per cent L.O.S.

[13] Unless stated otherwise the term mean or average refers to the arithmetic mean. Whenever geometric mean is used the term will be specifically stated.

Table 5.5. Levels of Inputs and Output in Paddy Production on per Farm and per Acre Basis; 1972-73 Maha Season--All Survey Farms

Variable		Per Farm		Per Acre	
		Geometric mean	Arithmetic mean	Geometric mean	Arithmetic mean
Y Output	(Bushels)	102.37	152.62	56.81	62.29
X_1 Land	(Acres)	1.8	2.45	-	-
Farm labour	(Man-days)	41.38	55.91	22.99	22.82
Non-farm labour	(Man-days)	63.77	81.92	35.43	33.43
X_2 Total labour[1]	(Man-days)	104.00	137.83	57.77	56.25
X_3 Fertilizer	(Rs.)	80.50	136.00	44.72	55.51
X_4 Agro-chemicals	(Rs.)	32.00	46.00	17.78	18.77
X_8 Draft services[2]	(Rs.)	199.00	334.00	110.00	136.33

[1] X_2 includes farm labour and non-farm labour.

[2] X_8 includes both animal and machinery services

labour requirement per farm for a Maha paddy crop amounted to 138 man-days, indicating a per acre labour utilization of 56 man-days. It was found that the family labour supply only accounted for 56 man-days of the total labour requirement with the rest represented by hired and exchange labour.

The average farm expenditure on fertilizer use was Rs.136.00 which amounted to Rs.55.51 per acre. The geometric mean fertilizer cost was still lower; the respective figures per farm and per acre being Rs.80.50 and 44.72 respectively. At an average price of Rs.23.00 per cwt.

the amount of fertilizer used per acre on a "typical" farm was 1.9 cwts.[14] The survey showed that all the farmers grew high yielding varieties of rice, which usually require 3-4 cwts. of fertilizer per acre for obtaining best yields. This straight away indicates an under use of fertilizer by farmers. The table also shows the average expenditure on animal and machinery services per farm was Rs.334.00, ranking as the second highest item of expenditure in paddy production. The average expenses on agro-chemicals input, e.g., herbicides, insecticides and fungicides, were only Rs.18.77 per acre.

c. Marginal Productivities of Inputs

Of the three productivity measures the most reliable and useful in guiding resource allocation decisions is marginal value productivity (MVP). It is defined as the addition to total value product resulting from the addition of one unit of an input to the production process, ceteris paribus. The estimates of input MVP's in paddy production at geometric mean levels and four other input level combinations are indicated in Table 5.6. The latter input combinations included (a) geometric mean input levels raised 50 per cent, (b) only draft services input increased 50 per cent, keeping others at geometric mean levels, (c) only fertilizer input increased 50 per cent, other inputs held at geometric mean levels and (d) fertilizer and labour each increased by 50 per cent holding other inputs at geometric mean. Accordingly, the MVP's of inputs

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[14] Implies geometric mean levels of inputs. One cwt. equals 112 lbs.

Table 5.6. Effects of Increasing (a) All Inputs, (b) Some Inputs on Marginal Value Productivities and Total Output--Based on Equation R_6

Resource Inputs	Geometric mean input levels (1)	MVP's of inputs (Rs.) (2)	Input level at 50 per cent above geometric mean (3)	Marginal Value Productivities (Rs.): All inputs at 50 per cent above geometric mean (4)	Only draft services at 50 per cent above geometric mean (5)	Only fertilizer at 50 per cent above geometric mean (6)	Only fertilizer and labour at 50 per cent above geometric mean (7)
		(per ac.)		(per acre)			
X_1 Land (Acres)	1.80	220.43	2.70	237.72	232.09	239.33	303.70
		(per m-d)		(per man-day)			
X_2 Labour (Man-days)	104.00	8.89	156.00	9.59	9.36	9.65	8.16
		(per Rs.)		(per rupee)			
X_3 Fertilizer (Rs.)	80.50	3.89	120.75	4.20	4.10	2.81	3.57
		(per Rs.)		(per rupee)			
X_8 Draft Services (Rs.)	199.00	.99	298.50	1.06	.69	1.06	1.35
Value of Output (Rs.)		1,543.83		2,497.42	1,625.21	1,676.29	2,137.10

calculated show what changes take place when resources are combined in different ways. Thus in relation to resource prices the MVP's point to profitable adjustments.

Columns (1) and (2) in Table 5.6. (p. 72) indicate geometric mean levels of inputs used on the survey farms and the corresponding input marginal value productivities, respectively. Column (2) shows that the value productivity of an acre of paddy land at the margin is Rs.220.43, while the marginal return from a man-day is Rs.8.89. Column (2) also indicates that an extra rupee used in either fertilizer or draft services would have brought an additional Rs.3.89 and Rs.0.99 respectively.

The levels of inputs shown in column (3) represent a hypothetical input combination, where all input levels are simultaneously increased 50 per cent above their geometric means. The corresponding marginal value productivities of inputs at these levels are given in column (4), which shows that all MVP's have now increased. The increase of all inputs by 50 per cent also increased the estimated total output from Rs.1543.83 to Rs.2497.42.

Columns (5) and (6) of Table 5.6 illustrate the point that increase in one input, keeping all other inputs at previous levels, serves to increase MVP's of the other inputs while decreasing its own MVP. For instance, a solitary increase in expenditure on draft services (column 5) by 50 per cent would lower its MVP from Rs.0.99 to 0.69, while increasing the MVP's of the other inputs. Thus, it is clearly seen that employing more draft services under the situation described, only serves to move further away from optimal allocation, because the MVP's of the inputs diverge further from their prices (see Table 5.7.).

From column (6) (Table 5.6. p. 72) it is seen that if fertilizer cost per farm alone is increased from Rs.80.50 to Rs.120.75, the MVP of draft services is increased to Rs.1.06 from Rs.0.99 while that of itself is reduced to Rs.2.81 from Rs.3.89. Therefore, the figures shown in columns (5) and (6) demonstrate that increased applications of a single input do not alter output as much as would occur if more resources were increased. This is clearly seen from the results in column (7), where both labour and fertilizer are increased simultaneously. Here, the increase in output is much higher than when either fertilizer or draft services alone was increased. In summary it can be said that the demonstrated changes in MVP's provide useful directions for resource adjustments under conditions posited.

Since the MVP of any resource decreases with higher levels of application, ceteris paribus, it is necessary to observe what happens at resource levels other than geometric means if optimal resource allocation is to be achieved. Nevertheless, MVP observations at geometric mean resource levels are of great use in helping farmers and extension personnel recognize typical needs for resource adjustments. To extend the analysis, MVP's were estimated at different levels of application, holding other inputs constant at their geometric means. The results are presented in Table 5.7.

From Table 5.7. it is seen that by increasing the fertilizer input per farm from Rs.80.50 to Rs.140.00 (other resources held at geometric

Table 5.7. Estimation of MVP's of Resource Inputs at Different Levels of Application (Assuming Geometric Mean Levels for Other Resources)--Based on Equation R_6

Resource Input	Unit Price (Cost)	Input level	MVP estimates (rupees)		Total product estimates (rupees)
		(acres)			
Land	227.50 (Rs./Ac.)	1.00	341.96	per acre	1,327.43
		1.50	307.40		1,473.22
		1.80*	220.43*		1,543.83*
		2.00	203.83		1,586.27
		2.50	172.64		1,679.39
Labour	6.10 (Rs./man-day)	(Man-days)			
		80.00	9.90	per man-day	1,322.25
		100.00	9.06		1,512.61
		104.00*	8.89*		1,543.83*
		120.00	8.39		1,681.88
		140.00	7.88		1,844.58
Fertilizer	1.00 (Rs.)	(Rs.)			
		60.00	4.92	per Rupee	1,454.42
		80.50*	3.89*		1,543.83*
		100.00	3.27		1,612.14
		120.00	2.81		1,674.17
		140.00	2.50		1,727.39
Draft Services	1.00 (Rs.)	(Rs.)			
		100.00	2.08	per Rupee	1,414.42
		150.00	1.38		1,489.28
		199.00*	0.99*		1,543.83*
		200.00	0.98		1,544.92
		250.00	0.83		1,589.27

* Indicates geometric means, also MVP's and total products at geometric mean input levels.

mean levels), the total output increased but the MVP dropped to Rs2.50. Even after the increase the MVP of fertilizer was still clearly above input price. Similarly, by increasing farm labour input from 104 to 140 man-days, total productivity increased with an accompanying decrease in MVP to Rs.7.88, which is still above input price. In contrast a cost increment for draft services from Rs.199.00 to Rs.250.00 resulted in an output increase which was insufficient to pay for the extra input. In this case the MVP became lower and even more divergent from price.

d. Distributive Shares of Individual Inputs of Production

An analysis involving the allocation of the total product to individual input factors is useful for identifying the relative contribution of inputs to total paddy output. Such an allocation of the total product to different input factors can be undertaken by using Euler's theorem. The theorem states that under conditions of linear homogeneity, the total product will be exhausted by the distributive shares for all the input factors if each factor of production is paid the amount of its marginal productivity.

The R_6 production function estimate in the present study shows returns to scale of 1.186. Therefore, an extension of Euler's theorem was used for obtaining the contribution of each input factor to the total product.[15] In the calculations, resources were assumed to be combined at geometric mean levels.

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[15] See Appendix 3 for account of method.

Table 5.8 illustrates that in the paddy production under study, labour accounts for the largest farm share of production, namely 50.6 per cent of total farm output. The land input share of total paddy output amounts to 21.6 per cent. The contribution of fertilizer and draft services variables are 17.0 and 10.8 per cent of the total output,

Table 5.8. Amounts of Value Product Contributed by Resource Inputs to Total Paddy Output (All Resources at Geometric Levels)--Based on Equation R_6

Resource Input		Resource Level	Amount of Value Product Contributed (Rs.)	Percentage Value Product Contributed
X_1 Land	(Acres)	1.8	333.90	21.65
X_2 Labour	(Man-days)	104.0	779.54	50.56
X_3 Fertilizer	(Rs.)	80.50	264.05	17.02
X_8 Draft services	(Rs.)	199.00	166.11	10.77
Total			1,543.60	100.00

respectively. A direct comparison between the costs of resources (see Tables 5.5. (p. 70) and 5.7. (p. 75)) and their value contributions to total production (see Table 5.8.) can also be made. At the geometric mean level, the total cost of labour input per farm was Rs.634.40, while its contribution to total output was Rs.779.54. The costs of fertilizer and draft services were Rs.80.50 and Rs.199.00 respectively and their corresponding value contributions to total output were Rs.264.03 and 166.11.

e. Average Apportioned Value Productivities and Farm Net Value Productivities of Farm Inputs

The average apportioned value productivity of a resource can be determined by dividing its level of application into its allotted value productivity (see Table 5.8, p. 77). The average apportioned productivities of the paddy inputs are given in column (3) of Table 5.9. The table indicates that the average apportioned productivity of an acre of paddy land for a cultivating season was Rs.185.50 Similarly the average apportioned productivity for a man-day of labour and Rs.1.00 of fertilizer was Rs.7.49 and Rs.3.28 respectively. The corresponding value for Rs.1.00 of draft services was Rs.0.83. Thus in relation to their prices the average apportioned productivities of labour and fertilizer are substantially higher than their per unit costs. On the other hand the average apportioned productivity of draft services is less than its cost.

Having determined the average apportioned value productivity of an input used in paddy production, it is now possible to compute its farm net value productivity. Thus, on multiplying average apportioned value productivity for an input by its geometric mean level of application and deducting associated costs, it is possible to obtain the farm net value productivity. However, this computation faces the problem of valuing farm inputs. Costing of inputs can adhere to different procedures. An economist may use opportunity cost as the basis, while a farmer may consider the cost to be his actual cash expenditure on the input. To overcome the problem of valuation, two types of cost assessment were used.

Table 5.9. Average Apportioned Value Productivities and Farm Net Value Productivities of Inputs in Paddy Production at Geometric Mean Input Levels--Based on Equation R_6

Resource (1)	Geometric mean level of input on farms (2)	Average apportioned value productivity on farms (Rs.) (3)	Market[1] cost of resource (Rs.) (4)	Farm based[2] cost of Resource (Rs.) (5)	Farm Net Value[3] Productivities of Inputs: Market costs deducted (Rs.) (6)	Farm Net Value[3] Productivities of Inputs: Farm based costs deducted (Rs.) (7)
X_1 Land (Acres)	1.8	185.50	227.50	165.00	-75.10	36.90
X_2 Labour (Man-days)	104.00	7.49	6.10	3.74	144.56	390.00
X_3 Fertilizer (Rs.)	80.50	3.28	2.00	1.00	103.93	183.54
X_8 Draft Services (Rs.)	199.00	0.83	1.00	0.62	-33.83	41.79
Total	-	-	-	-	139.56	652.23

[1] Determined under full opportunity cost considerations (e.g., Rs.6.10 per man-day of labour; fertilizer without subsidy). Costs relate to geometric mean levels of inputs.

[2] Reflects established land rent, mix of hired and family labour, subsidized fertilizer, and mix of hired and farm provided draft services. Costs relate to geometric mean levels of inputs.

[3] Farm Net value productivities are derived by deducting costs from input value productivity shares (see: Table 5.8. p. 77).

These types of costs are referred to as market cost and farm based cost determinations. The corresponding costs for an input are indicated in columns (4) and (5) of Table 5.9. (p. 79). The farm based cost of an input represents the total cash outlay involved in acquiring (hiring and purchasing) an input for paddy production, divided by the total number of units used. Here no charge is made for resources already on the farm, e.g., family labour. Market cost of an input reflects opportunity cost, which in the case of fertilizer was assessed at the unsubsidized rate.

Columns (6) and (7) of Table 5.9 present the computed farm net value productivities from individual inputs based on the different cost assessments. The land and draft services variables when valued at market cost result in negative farm net value productivities of Rs.75.10 and Rs.33.83 respectively, with regard to geometric mean levels of application. However, if farm based costs are used for valuation, they yield positive farm net value productivities of Rs.36.90 and Rs.41.79 respectively. In contrast, the fertilizer and labour variables show positive farm net value productivities for both types of costs. Fertlizer at market cost yields a figure of Rs.103.93, while at the farm based cost (i.e., after deducting subsidy) it yields Rs.183.54. This illustrates the benefit of the fertilizer subsidy to a farm, albeit at geometric mean levels of inputs. In summary, Table 5.9. shows that farm net value productivities for all inputs in equation R_6, added up to Rs.139.56 when valued at market cost and Rs.652.23 when valued according to farm based costs. The effect of full opportunity cost assessment is therefore clearly demonstrated.

f. Assessment of Input Allocative Efficiency

The analytical procedure followed in this section defines input allocative efficiency in terms of profit maximizing behaviour of paddy farmers. Two ways of assessing the efficiency of input allocation will be considered. Firstly, the marginal value productivities (MVP's) of inputs at geometric mean levels in the sample will be compared with corresponding marginal factor costs (MFC's). Secondly, optimal resource combinations will be compared with actual geometric mean levels of input application. From previous discussion of theory it is clear that these two approaches provide ready criteria for judging whether optimal resource allocation has been approached closely or not, under the assumption of unlimited capital.

(i) Comparison of MVP's and MFC's of Paddy Inputs

The results of comparing input MVP's and MFC's in paddy production are presented in Table 5.10.

With the absence of capital limitations or other restrictions on the application of an input, a ratio of 1 between its MVP and MFC would indicate that the most efficient allocation for the resource had been achieved under certain conditions. It is very important that these conditions are clearly understood.

The production function in the form of R_6 shows increasing returns to scale for the variables included in the relationship. It is therefore impossible to have all inputs allocated in a way that their MVP's equal MFC's at an optimal output level for that could only happen if the sum of production elasticities of inputs was less than 1. Therefore, the

Table 5.10. Comparison of Marginal Value Productivities[1] and Marginal Factor Costs of Inputs in Paddy Farming at Geometric Mean Levels of Application--All Survey Farms--Based on Equation R_6

Resource Input		MVP[1] (Rs.)	MFC (Rs.)	Ratio of MVP to MFC
(1)		(2)	(3)	(4)
X_1 Land	(acres)	220.43 (18.71)	227.50	.96
X_2 Labour	(man-days)	8.89 (0.73)	6.10	1.46*
X_3 Fertilizer	(Rs.)	3.89 (0.14)	1.00	3.89*
X_8 Draft services	(Rs.)	0.99 (0.60)	1.00	.99

[1] Figures in parenthesis indicate the standard errors of MVP estimates.

* Null hypothesis that ratio equals 1 was rejected at 1 per cent.

The standard error of MVP estimate of each production input was calculated from the formula,

$$SEP_{X_i} = \frac{\overline{Y}}{\overline{X}_i} . S_{b_i}$$

where $\overline{Y}$ is the geometric mean value of output, $\overline{X}_i$ is the geometric mean value of input, and S_{b_i} is standard error of the regression coefficient b_i with regard to X_i. See E.O. Heady and J. Dillon, Agricultural Production Functions, Iowa State University Press, 1961, p. 231.

Since all the MVP estimates were made at the input geometric mean levels using the Cobb-Douglas function, the more complex variance formula for determining the standard errors of estimate developed by Carter and Hartley was not applied. See H.O. Carter and H.O. Hartley, "A variance Formula for Marginal Productivity Estimates using the Cobb-Douglas Function," Econometrica, 26: April, 1958, pp. 306-313.

usefulness of seeing how close MVP's are to MFC's at geometric levels of input application for the survey farms is somewhat restricted.

Under the assumption that typical farmers are free to vary an input while holding other inputs constant at the geometric mean levels, it is efficient practice to bring the MVP of the variable input into equality with its MFC. This is indeed possible even with the R_6 equation. Hence Table 5.10., under the conditions described, indicates what adjustments can be recommended. Here it can be noted that the ratio of MVP to MVC, in column 4 of Table 5.10. for each factor input, was statistically tested with respect to the null hypothesis that the ratio equalled 1. The results of the tests show that the ratios for land and draft services were not rejected as being equal to one. Therefore in the restricted equilibrium sense described these inputs show efficient allocation. In the case of labour and fertilizer the ratios were rejected as being equal to one. Therefore, since their MVP's are higher than their MFC's, it is clear that many farmers could have afforded to use more of these inputs under the assumptions specified.

It appears that paddy farmers in Sri Lanka have been concerned with achieving efficient uses of land and draft services. In contrast, labour and fertilizer allocation appears to present a problem. The under utilization of fertilizer can be explined to a large extent in terms of cash shortages suffered by most farmers, as well as the rather high degree of risk associated with output in paddy farming. But, the under utilization of labour may be rather surprising at first sight, if the common view is held that the MVP of rural labour in subsistence economies is zero or near zero.[16] The usual argument for assuming a zero MVP for labour is that a surplus of farm labour exists and a lack of alternative means of employment in subsistence economies ensures conditions, whereby, it is readily employed to the point of zero MVP. In the case of the Sri Lanka data it is obvious that farmers cannot afford to see the MVP of labour go below the wage rate (at least for hired labour), let alone see it go to zero. The interesting point is that equation R_6 shows the MVP of labour remaining well above the wage rate for the typical farmer.

The relatively high MVP of labour in paddy cultivation at geometric mean levels of inputs is explained reasonably well by the pattern of seasonal labour distribution. It shows critical periods of heavy labour demand for operations such as land preparation, transplanting, harvesting and threshing. During these peak periods, family labour is hardly adequate and on most paddy farms additional labour, often hard to find, has to be hired. This situation is evident from the data in the present study. As indicated in Table 5.5. (p. 70) nearly 60 per cent of labour for paddy production came from hired labour.

Again, the existence of shortages of labour for paddy production in the sample areas are confirmed by the in-migration of farm labour during peak periods of paddy farming.[17] Thus inadequate labour supplies

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[16] The doctrine of zero marginal productivity of rural labour in developing economies has been refuted by a number of economists: see, T.W. Schultz, Transforming Traditional Agriculture, New Haven and London, Yale University Press, Chapter 4, 1969.

[17] This can be observed particularly in the districts of Hambantota and Polonnaruwa.

during critical periods would help to explain the relatively high MVP of labour.

(ii) Comparison of Optimal and Geometric Mean Levels of Input Application

Another way of examining the efficiency of resource use of the typical paddy farmer is to compute the optimal combination of resources from the production function R_6, with regard to the geometric mean output level per farm of Rs.1543.80 and the geometric mean paddy acerage of 1.8 acres. Land is an input that meaningfully lends itself to constraint. The optimal combination of labour, fertilizer and draft services under these conditions can then be compared with the actual levels of their use.

When paddy land is fixed at 1.8 acres per farm, the equation R_6 becomes:

$$Y = 20.0313\, X_2^{.5987}\, X_3^{.2030}\, X_4^{.1272} \qquad [5.12]$$

The exponents in this function sum to 0.9289. Theoretically it is now possible to determine an optimal level of output as well as the corresponding combination of inputs. But it is not practicable to do that because it means extrapolating beyond the relevant range of the data. This is easily explained by the fact that the coefficients come close to adding up to unity, which means that the optimum position occurs a considerable way along the expansion path. Nevertheless, under this situation it is still possible to compute the optimal proportions of inputs to produce a desired level of output, within the relevant range of data. Accordingly, if output is fixed at the geometric mean level of Rs.1543.80

and land is held at the geometric mean level of 1.8 acres, the optimum combination of labour, fertilizer and draft services is given in Table 5.11 below.

Table 5.11. Comparison of Actual and Optimal Levels of Inputs at the Geometric Mean Output of Rs.1543.80 and the Geometric Mean Input of 1.8 Acres--Based on Equation R_6

Input (1)		Current Amounts of Inputs (2)	Optimal Amounts of Inputs (3)	Current Proportions[4] of Inputs (4)	Optimal Proportions[4] of Inputs (5)
X_1 Land[1]	(Rs.)	409.50	409.50	1.00	1.00
X_2 Labour[2]	(Rs.)	634.40	589.32	1.55	1.44
X_3 Fertilizer[3]	(Rs.)	80.50	165.44	.19	.40
X_4 Draft Services	(Rs.)	199.00	125.59	.48	.30

[1] Land was valued at Rs.227.50 per acre.

[2] Labour was valued at Rs.6.10 per day.

[3] Fertilizer and draft services valued at Rs.1.00 per unit.

[4] Land was used as the numeraire.

Columns (2) and (3) of the table indicate the current and optimal investments in variable inputs for producing an output of Rs.1543.80 under the land situation specified. The respective input investment proportions are given in columns (4) and (5). Thus in optimal combination labour and draft services show a decrease over the current amounts; whereas fertilizer shows an increase. These results have real meaning for resource adjustment on the typical farm. They indicate a redistribution of investment; away from labour and draft services, into fertilizer. At first sight this result might seem inconsistent with the earlier partial equilibrium findings. For instance in that case it was found that labour and fertilizer MVP's were higher than their MFC's when calculated at geometric mean input levels. Now the suggestion is made that investment can be redirected from labour and draft services into fertilizer. The two sets of findings are consistent within the strict contexts of analysis. In the latter case simultaneous adjustment between labour, draft services and fertilizer is being sought. In the earlier analysis statements concerning labour were based on the fact that all other inputs were held fixed at geometric mean levels.

There is still another facet of resource allocation which should be treated for the survey data. It calls simply for a definition of the expansion path (resource combination) relationships specified by the R_6 production function and input prices. A Cobb-Douglas production function in four independent variables of the type used, leads to simultaneous expansion path relationships between resources as follows:[18]

$$X_2 = \frac{b_2 \, P_{x1}}{b_1 \, P_{x2}} (X_1)$$

where: X_1, X_2, X_3, X_8 are independent variables;

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[18] These equations can be easily verified by simple algebraic interpretation of production theory. They follow the definition given by A. B. Anderawewa in "Supply Response in Grain Corn in S.W. Ontario," unpublished M.S.A. Thesis, University of Toronto, 1961.

$$X_3 = \frac{b_3 \; P_{x1}}{b_1 \; P_{x3}} \; (X_1)$$

P_{x1}, P_{x2}, P_{x3}, P_{x8}, are the corresponding input prices and

$$X_4 = \frac{b_4 \; P_{x1}}{b_1 \; P_{x8}} \; (X_1)$$

b_1, b_2, b_3, b_8, are the corresponding elasticity coefficients from the R_6 function.

From this set of equations it is possible to solve for the level of X_1 with regard to any output level. After that all other input levels can be calculated. Even when no particular output level is considered the expansion path relationships still define the fixed proportions in which inputs will be combined at all output levels.

With regard to the R_6 production function and input prices, the fixed proportions for input combination are:

$$X_2 = 86.81 \; X_1$$

$$X_3 = 179.47 \; X_1$$

$$X_8 = 112.28 \; X_1$$

Where, X_1 is land in acres, X_2 is labour in man-days, X_3 is fertilizer in rupees and X_8 is draft services in rupees. Therefore, it is possible to tell at a glance whether resources on any farm are out of line with optimal combination conditions defined by the expansion path. Referring to the geometric mean input levels for the survey farms (Table 5.5., p. 70), it is clear that in relation to land commitment there is considerable under-utilization of labour and fertilizer. In fact the recommended levels of inputs with 1.8 acres of paddy would be approximately 156 man-days of labour, Rs.323.00 of fertilizer and Rs.202.00 of draft services. The actual geometric mean input combination with 1.8 acres of paddy was 104 man-days of labour, approximately Rs.81.00 of fertilizer and Rs.199.00 of draft services. If the optimal input combination were achieved it would give Rs.2606.00 of paddy output, which exceeds the geometric mean output level of Rs.1544.00. With the definition of the expansion path equations it is but a short step to calculate the best input combination for any given level of output. For example, in the case of the Rs.1544.00 (geometric mean) output level, the recommended inputs are 1.18 acres of land and approximately 99 man-days of labour, Rs.205.00 of fertilizer and Rs.128.00 of draft services. The typical farmer in the survey was using too much land, labour and draft services, and not enough fertilizer to attain the same output. In other words he was not sufficiently intensive in his use of labour and fertilizer.

It is obvious that the foregoing analysis centering on the expansion path input relationships, is of great help in measuring input efficiency on paddy farms and providing directions for resource adjustments.

PART B

ANALYSIS OF RESOURCE PRODUCTIVITIES IN PADDY PRODUCTION AT THE REGIONAL LEVEL

This section deals with resource productivity analysis of paddy data for individual regions within the main sample. The discussion is divided into five sections, dealing with:

(1) the need for identifying different productivity regions in paddy production;

(2) actual identification of the regions;

(3) estimation of regional production functions;

(4) assessment of resource utilization at the regional level;

(5) resource productivity analysis at the district level.

1. Need for Identifying Different Productivity Regions in Paddy Production

The productivity analysis and interpretation of results in section A above were based on data for the total sample of survey farms. Since these farmers were originally selected as representing a number of districts, an important assumption implied in the analysis was that a single production function could represent them all. The results obtained so far have not suggested that this assumption is seriously at fault. Nevertheless in view of there being two area types in the total sample, namely farms in wet and dry zones (not based on the Maha season, which is equally wet for both, but depending on the rest of the year), it was thought useful to carry out a regional analysis on stratified data. This would serve the purpose of testing the accepted view that the dry zone is a higher responding area in terms of inputs and output. Regional analysis also serves to make the study comprehensive in treatment no matter what the outcome. Therefore, in order that any heterogeneity in quality of inputs in the total survey data be reduced as much as possible, attention was turned to appropriate stratification of the sample. In so doing it was hoped that regionally grouped data would show greater homogeneity which would permit production functions to be estimated more precisely. Furthermore establishment of district productivity areas also has an additional advantage since it affords greater local specificity in resource adjustment. However, stratifying the main sample into too many parts is to be avoided because it would reduce the number of observations for any particular production function estimation and render it more difficult to establish statistical relationships. Even under assumed low and high response region stratification the farm samples become small enough to affect estimation in this way.

2. Identification of Regions

Different rice producing districts in Sri Lanka can show variations in respect of quality and quantity of inputs as well as in certain climatic conditions. On the basis of available information on production techniques and observed ecological characteristics, it was hypothesized that the five distinct productivity regions can be divided into what will be termed "high response" and "low response" regions. The high response region was assumed to be more productive and includes the districts of Polonnaruwa and Hambantota. The low response region includes the districts of Kurunegala, Colombo and Kandy. Hence the high response region corresponds to the "dry" zone,[19] while the low response region corresponds approximately to the "wet" zone[20] of the island.

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[19] Sri Lanka can be broadly divided into two major agricultural areas namely dry and wet zones. The line of demarcation is the 75 inches annual rain fall line.

[20] In a strict geographical classification Kurunegala district falls within the "intermediate" zone.

Prior to estimating separate production functions for the two regions it seemed necessary to test whether the two hypothetical sub-groups of farms did in fact reveal significant differences in paddy production. Two procedures were used for this purpose. They are:

(a) the dummy variable method in regression analysis, and

(b) the discriminant analysis method for statistically testing any differences observed between groups.

(a) Dummy Variable Method

This method involves the use of a zero-one dummy variable in the Cobb-Douglas function to account for regional differences in productivity.[21] The value of one was used for farms in the designated high response region, while zero was used for those in the low response region. The dummy variable method permits the advantage of pooling farm data from all regions for the purpose of regression. The estimated Cobb-Douglas production function incorporating the relevant production inputs and the regional dummy variable is reported in Table 5.12.

The results indicate that all regression coefficients including the regional dummy variable are statistically significant at the .05 L.O.S. The inclusion of the regional dummy variable implies that the two hypothesized regions can in fact be represented by the same production

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[11] For statistical properties and application of the dummy variable technique see: Arthur A. Goldberger, Econometric Theory, New York, Wiley and Sons, Inc., pp. 218-227, 1964. For specific application to production function estimation see: Zvi Griliches, "Research Expenditures Education and the Aggregate Agricultural Production Function," Amer. Econ. Rev., 54: Dec. 1964, pp. 963-974, and Daniel B. Suits, "Use of Dummy Variables in Regression Equations," Jour. Amer. Stat. Assoc., 52: 1957, pp. 548-551.

elasticities of inputs. The function therefore discriminates between the regions by way of the dummy variable term. The latter serves to shift the total product level.

Table 5.12. Cobb-Douglas Production Function Coefficients[2] --Total Farm Data--All Survey Farms (Regional Dummy Variable Included)

Constant	Land (X_1)	Labour (X_2)	Fertilizer (X_3)	Draft Services (X_8)	Regional Dummy (D_1)	R^2
23.665	.2601*	.5592*	.1875*	.1013**	.1743*	.9451
	(.0815)	(.0802)	(.0351)	(.0502)	(.0571)	

[1]Natural values for the regional dummy variables are 2.71828 and 1 for high and low response regions respectively.

[2] Parenthesis indicate standard errors of the coefficients
* H_0 : $\beta = 0$ rejected at .01 L.O.S. ** H_0:β=0 rejected at .05 L.O.S.

(b) Discriminant Analysis Method

This constitutes a powerful statistical approach, originally suggested by Fischer,[22] for separating two normally distributed populations on the basis of a set of characteristics. In this method a number of variables X_i, i = (1,2, ...n) are hypothesized as assisting in discriminating between the proposed groups. A classification function capable of discriminating among groups is then derived. The latter is of the form:

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[22] R. A. Fischer, "The Use of Multiple Measurements in Taxonomic Problems," Annals of Eugenics, 13: 1936, pp. 179-188.

$$D = a_1 + v_1 X_1 + v_2 X_2 + \ldots\ldots\ldots v_n X_n \qquad [5.13]$$

where, the coefficients v_i of the linear function D = D (x) are computed so that the ratio of the sums of squares between group means to sums of squares within group means is maximized. Hence, the discriminant function can be considered as the linear function that maximizes this ratio. There is no other linear combination of the n variables having more discriminating power than the function obtained. In this way variables selected as contributing to differences between the two regional groups of farms were: land area (X_1), labour man-days (X_2), fertilizer cost (X_3), machinery services (X_4), and animal services (X_5). The mean values of the variables used for discriminating between the two regions are given in Table 5.13.

Table 5.13. Arithmetic Mean Levels of Input Application on Paddy Farms in Low and High Response Regions--Incorporating Total Survey Data

Variable		Low response region[1]	High response region[1]
X_1 Land	(acres)	1.35	4.32
X_2 Labour	(man-days)	87.88	215.11
X_3 Fertilizer	(Rs.)	57.09	274.82
X_4 Machinery Services	(Rs.)	96.15	426.22
X_5 Animal Services	(Rs.)	76.49	181.74

[1] High response region includes the districts of Polonnaruwa and Hambantota. Low response region includes the districts of Kurunegala, Colombo and Kandy.

The data in Table 5.13. (p. 94) shows that the average levels of inputs for paddy production in the high response region are substantially higher than those in the low response region. It is also seen that the farms in the high response region used less animal power and more tractor power, while those in the low response region showed the opposite situation. Classification functions for the two regional groups of farms in the high and low response regional were computed and the results are given in Table 5.14.[23]

Table 5.14. Classification Functions for Rice Farms in Low and High Response Regions--Incorporating Total Survey Data

Region	Multi-linear classification function[1]	F value for testing group means[2]
1. Low response region	$D_1 = -1.6851 + .0034\ X_1 + .0199\ X_5$	
		49.66
2. High response region	$D_2 = 1.5923 + .0081\ X_1 + .0091\ X_5$	

[1] X_1 and X_5 refer to land and animal services variables.

[2] H_0: no difference between regions is rejected at .05 L.O.S.

[23] The computing procedure is illustrated in User Manual, UBC BMDO 7M (March, 1975, revision), Computing Centre, The University of British Columbia. See also T.W. Anderson, An Introduction to Multivariate Analysis, New York, John Wiley and Sons, 1958, p. 374.

The computed F value for testing the two regional arithmetic ($\overline{D}$, and $\overline{D}_c$) means was significant at the .05 L.O.S. This would indicate that the two sub-groups of farms can be judged distinctly separate on the basis of the classification functions. The classification functions incorporate the two most important variables for discriminating between the regions. If the variances of the variables included in a classification function are almost equal, the values of their corresponding coefficients provide measures of the relative importance of each variable to the total "discriminatory power" of the function. The discriminant analysis also indicated that 81.65 per cent of the farm units are suitably classified under the hypothesis of high and low response regions. This finding does not necessarily show that homogeneity of data is lacking when no regional separation is used. It does point specifically to differences in resource organization which may of course lead to differences in productivity due to input heterogeneity. Using mean values of the variables in each classification function makes it possible to compute mean values of the functions for the two regions. The mean values computed for the classification functions for high and low response regions were 3.281 and .151 respectively. The average of these two values is 1.716. Hence, if the classification functions were to be used for assigning farms into low and high response regions, those farms with a classification function value greater than 1.716 would be classified in the former, while those below 1.716 would be placed in the latter. It is seen that the farms most liable to be misclassified are those with a value close to 1.716.

3. Estimation of Regional Production Functions for High and Low Response Farming Regions

Since it has been shown that any input heterogeneity on the survey farms is likely to be successfully handled by dividing them into two distinct regional groups it now becomes relevant to estimate a separate production function for each region. Accordingly, production functions were estimated for the regional data using a linear and non-linear production relationships.

The results from different specifications of the multi-linear regression model are presented in Table 5.15 by equations R_{10}-R_{14} and R_{20}-R_{24} for low and high responsive regions, respectively. It is seen that production relationships in the two regions cannot be satisfactorily represented by these linear functions. Coefficients of major variables such as land and fertilizer are shown to be statistically non-significant, and, furthermore, they have large standard errors. The constant terms in all estimated regression equations are negative, and except in R_{10} and R_{11} they are not statistically significant. Therefore, the regression relationships were re-estimated on the assumption that a Cobb-Douglas function would prove more satisfactory. The results of this approach are reported in Table 5.16.

From Table 5.16. it is seen that in contrast to linear functions, the Cobb-Douglas type functions fit reasonably well to farm data in both low and high response regions. The equations R_{15}-R_{19} and R_{25}-R_{28} show high R^2 values ranging from .818 to .933. The equations R_{15}-R_{19} in low response region show that machinery and animal services variables become statistically non-significant when included separately. However,

Table 5.15. Multi-linear Production Functions for Paddy Farms in Low and High Response Regions--Incorporating Total Survey Data

	Low Response Region					High Response Region				
Regression Number	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}	R_{20}	R_{21}	R_{22}	R_{23}	R_{24}
R^2	.943	.940	.931	.930	.921	.925	.922	.924	.920	.882
Independent Variable[1]										
X_1 Land (Acres)	48.199	147.891	143.050	175.902**	236.859**	308.616	232.485	344.52	267.089	121.302
	(96.07)	(82.80)	(100.756)	(87.448)	(98.884)	(160.765)	(147.126)	(154.047)	(142.729)	(166.003)
X_2 Labour (Man-days)	6.653*	7.246*	6.177*	6.459*	6.811*	8.847*	9.667*	9.106*	10.727*	11.076*
	(1.248)	(1.239)	(1.358)	(1.285)	(1.341)	(1.977)	(1.852)	(1.943)	(1.803)	(1.144)
X_3 Fertilizer (Rs.)	3.715*	2.968	3.649	3.349*	3.643*	2.072	2.086	2.054	2.065	-.491
	(1.055)	(1.645)	(1.555)	(1.059)	(1.109)	(1.571)	(1.578)	(1.564)	(1.577)	(1.744)
X_4 Machinery services (Rs.)	-.276	.279	-	-	-	3.476*	2.626*	-	-	-
	(.672)	(.621)				(1.057)	(.758)			
X_5 Animal services (Rs.)	.983	1.285	-	-	-	4.016*	3.265*	-	-	-
	(.710)	(.812)				(1.230)	(1.042)			
X_6 Agro-chemicals (Rs.)	4.119*	4.524*	4.756*	4.868*	-	-8.144**	-9.263*	6.4971*	10.782*	-
	(1.693)	(1.722)	(1.844)	(1.826)	-	(3.743)	(3.007)	(1.052)	(2.567)	
X_7 Seed material (Rs.)	5.262	-	1.866	-	-	6.941	-	9.300*	-	-
	(4.741)		(2.800)			(6.041)		(2.799)		
X_8 Draft services (Rs.)	-	-	.104	.300	.438	-	-	-	2.553*	3.089*
			(.726)	(.660)	(.694)				(.754)	(.890)
Constant	-163.382*	-152.032*	-88.319	-89.870	-93.744	-65.402	-128.099	-38.656	-103.005	-135.000
	(53.358)	(54.330)	(53.290)	(49.29)	(55.765)	(270.189)	(265.796)	(267.028)	(264.403)	(316.906)

[1] Variables are defined in Chapter IV. Parentheses indicate standard errors.

* Statistically significant at .01 L.O.S.

** Statistically significant at .05 L.O.S.

Table 5.16. Cobb-Douglas Production Functions for Paddy Farms in Low and High Response Regions--Incorporating Total Survey Data.[1]

	Low Response Region					High Response Region			
Regression Number	R_{15}	R_{16}	R_{17}	R_{18}	R_{19}	R_{25}	R_{26}	R_{27}	R_{28}
R^2	.933	.921	.925	.820	.818	.841	.830	.846	.836
Independent Variable[2]									
X_1 Land (Acres)	.202	.459*	.132	.264*	.276*	.326**	.383*	.174	.103*
	(.122)	(.093)	(.126)	(.109)	(.089)	(.162)	(.096)	(.086)	(.049)
X_2 Labour (Man-days)	.411*	.460*	.450*	.492*	.502*	.429*	.416*	.445*	.500*
	(.094)	(.099)	(.094)	(.093)	(.094)	(.115)	(.108)	(.095)	(.108)
X_3 Fertilizer (Rs.)	.191*	.178*	.172*	.145*	.166*	.283*	.287*	.258*	.156*
	(.053)	(.056)	(.052)	(.051)	(.050)	(.064)	(.068)	(.059)	(.060)
X_4 Machinery services (Rs.)	-.027	-.028	-	-	-	.027	.031	-	-
	(.016)	(.017)				(.024)	(.022)		
X_5 Animal services (Rs.)	.019	-.012	-	-	-	-.029**	.087	-	-
	(.018)	(.017)				(.013)	(.062)		
X_6 Agro-chemicals (Rs.)	.016	-	-	.062	-	-.092**	-.089	.114	-
	(.019)			(.046)		(.040)	(.050)	(.071)	
X_7 Seed material (Rs.)	.299	-	.222	-	-	.054	-	-	-
	(.130)		(.115)			(.126)			
X_8 Draft services (Rs.)	-	-	.076	.156**	.174*	-	-	.299*	.313*
			(.092)	(.074)	(.063)			(.093)	(.107)
Constant	70.328**	52.091**	16.102**	23.196**	23.289*	51.008*	62.364*	18.065*	15.059*
	(2.034)	(2.017)	(1.306)	(1.537)	(0.815)	(1.069)	(1.519)	(0.521)	(0.597)
Sum of Elasticities	1.111	1.057	1.052	1.119	1.118	.998	1.113	1.290	1.072

[1] Correlation Matrices are presented in Appendix, Tables 7 and 8. These refer to logarithmic values of variables and may be expected to be similar to those for untransformed data.

[2] Variables are defined in Chapter IV. Parentheses indicate standard errors (those for constant term refer to log-linear equation).

* Statistically significant at .01 L.O.S.   ** Statistically significant at .05 L.O.S.

when these two variables are included in the function as a composite variable, namely, the draft services variable, the latter shows statistically significant coefficient. This is seen in R_{18} and R_{19}. The highest R^2 for low and high response areas are given by equations R_{15} and R_{25}, respectively. Unfortunately a number of coefficients in these functions are non-significant. Equations R_{19} and R_{28} representing each region have statistically significant coefficients and also show high R^2 values. These functions are judged statistically the most satisfactory. They are: for the low response region,

$$Y_L = 23.289\, X_1^{.2761}\, X_2^{.5023}\, X_3^{.1660}\, X_8^{.1744} \qquad [5.14]$$

and for the high response region,

$$Y_H = 15.059\, X_1^{.1030}\, X_2^{.5002}\, X_3^{.1561}\, X_8^{.3131} \qquad [5.15]$$

where the variables X_1, X_2, X_3, and X_8 represent land, labour, fertilizer and draft service inputs respectively.

Tests on the coefficient estimates of the low response region equation show that the corresponding population parameters could all take values as estimated by equation R_6 for the total farm sample. Hence, null hypotheses were not rejected at .01 L.O.S. When similar tests were performed for the high response region equation, null hypotheses were not rejected at .01 L.O.S. in all cases except for the land coefficient.

It is possible to test coefficients in the R_6 equation to see whether in relation to the standard errors, the corresponding population parameters could take values estimated for the regional functions.

To place stress on such tests would put the onus of showing differences the wrong way around. Even if it were done the earlier observations for null hypotheses at the .01 L.O.S. would only change with regard to the alpha constant term for the low response region equation and the land and draft services regression coefficients in the high response region equation. Then in the case of the first, the null hypothesis that the population alpha constant could equal the estimate given by the low response region equation was rejected. In the case of the land and draft services regression coefficient estimates in the high response region equation, the former was judged to be a value that the corresponding population parameter could take in the total sample equation. The opposite was true for the draft services coefficient.

In conclusion one cannot but note that these findings along with the fact that regional function R^2 values were lower than that shown by equation R_6, do not show that the regional functions are much improvement over the R_6 function. In fact the high response region function leads to certain difficulties in application as will be shown later. Nevertheless, the information provided by the regional functions is such that it serves as a new basis for studying resource productivities, thereby, permitting a useful comparison with previous results.

4. Assessment of Resource Productivities at the Regional Level

Results from the analysis of resource utilization at the regional level are reported in this section. The specific aspects that will be dealt with are:

(a) marginal value productivities of inputs;

(b) effects of changing input levels on total paddy output,

(c) intensities of resource use in low and high response regions.

(a) MVP's of Inputs in Low and High Response Regions

Determination of MVP estimates for inputs was based on production function equations [5.14] and [5.15] (p. 100). The derived marginal value productivities for the corresponding geometric mean levels of inputs are reported in Table 5.17., columns (3) and (5).

Table 5.17. Marginal Value Productivities and Corresponding Geometric Mean Levels of Inputs per Farm in Low and High Response Regions.

Variable (1)		Low Response Region		High Response Region	
		Geometric Mean Level of input (2)	MVP (Rs.) (3)	Geometric Mean Level of Input (4)	MVP (Rs.) (5)
X_1 Land	(Acres)	1.115	233.58	3.55	136.72
X_2 Labour	(Man-days)	62.40	7.59	195.00	12.09
X_3 Fertilizer	(Rs.)	40.80	3.83	201.00	3.65
X_8 Draft services	(Rs.)	274.82	0.59	460.00	3.20

Study of MVP values for regional production inputs indicates a considerable degree of maladjustment of resource use. This is noticeable particularly in the case of fertilizer and draft services. Fertilizer shows high MVP's amounting to Rs.3.83 and Rs.3.65 in the low and high response regions at geometric mean levels of application. This indicates an under-utilization of fertilizer on the typical farm in both regions.

On the other hand the draft services input indicated over-use in the low response region and substantial under use in the high response region. The MVP of draft services in the high response region suggests that it is almost as important as that for fertilizer in the same region in indicating under-utilization. This observation is probably explained by the shortage of buffaloes and tractors during peak periods of farming. In contrast, the extremely low MVP of draft services in the low response region is not easily explained, although it may be explained by an adequate supply of buffaloes for farm operations in the region.

At geometric mean level the MVP of labour in the low response region amounts to Rs.7.59 which is almost equal to the prevailing wage rate. In the high response region, labour shows an MVP of Rs.12.09 which is very much greater than the farm wage rate. This again suggests a production situation suffering from restricted labour. It is evident from Table 5.17 (p. 102) that the marginal value productivity of land in the high response area is substantially lower than that for the low response area. The important fact to note is that too much land is used on a typical farm in high response regions in relation to other levels of resources. The price of land services was approximately 228 rupees. Therefore, the MVP of land in the high response region is well below this figure, while the MVP of land in the low response region is almost equal to the price of land services.

The preceeding comments are important in the context of varying a single resource and holding other resources fixed as stated geometric mean levels. It will be noted that both areas show increasing returns to scale for their production functions, which means that optimum outputs cannot be recommended. Rather, resources for any given output should be combined in line with expansion path proportions as explained earlier in the chapter. Of course holding one or more inputs fixed in the equations will allow optimal outputs and resource combinations to be determined owing to diminishing marginal productivity conditions.

Turning to the expansion path mode of analysis, which was introduced in the previous section, it is useful to apply it to the regional functions R_{19} and R_{28}. From the information given in Table 5.18 it is obvious that the geometric mean levels of inputs in the high and low response regions are out of line with recommended expansion path resource combinations.

In the case of the low response region the optimal proportional mix of inputs is one acre of land combined with approximately 68 man-days of labour, Rs.137 of fertilizer and Rs.144 of draft services. These proportions show that input commitment at geometric mean levels was insufficiently intensive in fertilizer and labour, with the former being most under-utilized. Draft services, however, in relation to the geometric mean acreage of 1.12 acres were shown to be used over-intensively.

When the optimum resource mix is calculated for the geometric mean output per farm (Rs.1130) in the low response region, the findings are that the typical farmer employed close to the recommended land area, too many draft services, and insufficient labour and fertilizer. Lack of intensive use of fertilizer is shown by the actual use of approximately Rs.41 worth on 1.12 acres compared with the optimal use of Rs.147 worth on 1.07 acres.

Table 5.18. Expansion Path Resource Combinations for Low and High Response Regions at Geometric Mean Levels of Output--Incorporating Total Survey Data

EXPANSION PATH INPUT COMBINATIONS[1]	
Low Response Region	High Response Region
Labour X_2 = 67.85 X_1 (Land Acres) (Man-days)	Labour X_2 = 181.12 X_1 (Land Acres) (Man-days)
Fertilizer X_3 = 136.78 X_1 (Rs.)	Fertilizer X_3 = 344.78 X_1 (Rs.)
Draft Services X_8 = 143.70 X_1 (Rs.)	Draft Services X_8 = 691.33 X_1 (Rs.)
EXPANSION PATH INPUT COMBINATIONS[1]	
For Geometric Mean Output Rs.1129.87	For Geometric Mean Output Rs.5166.85
X_1 = 1.07 (Acres)	X_1 = 1.30 (Acres)
X_2 = 72.93 (man-days)	X_2 = 234.87 (man-days)
X_3 = 147.01 (Rs.)	X_3 = 447.12 (Rs.)
X_8 = 154.45 (Rs.)	X_8 = 896.52 (Rs.)

[1] Based on R_{19} and R_{28} production function estimates for Low and High Response Regions, respectively (see Table 5.16, p. 99).

In understanding these results it should be recalled that the regional production functions indicate increasing returns to scale for the variables included. Therefore, when all inputs are assumed variable optimal output levels cannot be calculated. Of course when one or more variables are fixed the functions will permit optimum outputs to be determined. Nevertheless, expansion path output combinations are very useful in guiding resource adjustments and allocation, especially in relation to given output levels.

Unfortunately the derived expansion path equations for input combinations in the high response region do not permit confidence to be placed in their application. The reason for this is that a smaller number of sample units (44 observations) has contributed to estimation of the expansion path, which quickly defines levels of resources, other than land, to lie outside the relevant ranges of sample data and for that matter paddy production data in general. Consequently, the calculations for optimal input levels at the geometric mean level of output per farm (Rs.5167), are very high--much higher than the actual geometric means--for all inputs other than land, which at 1.3 acres is surprisingly smaller than the actual geometric mean level of 3.55 acres. If one were to extract any useful information from this analysis for the high response region, it would be that land is used too extensively, and fertilizer, labour and draft services should be used more intensively. But even here the proposition of more intensive use of draft services must be treated cautiously, since it is the first occasion in the study that this input has been shown to be under-utilized. Coupling this with the comments above regarding the suitability of the derived relationship, this particular finding constitutes no more than an hypothesis. Interestingly enough, however, the high response region has been observed by some researchers to suffer from draft power shortages. Therefore, there may be some grounds for thinking that the hypothesis may be true.

(b) Effects of Changing Input Levels on Total Paddy Output

A criterion that can be useful in adjusting resource inputs within and between regions is the production elasticity of a specific input. This elasticity is defined as the percentage change in production arising from a one per cent change in the input level, *ceteris paribus*. In a Cobb-Douglas production function these elasticity measures are given by the respective input coefficients. The production elasticities of different inputs in the low and high responsive regions are presented in Table 5.19., and are provided by the Cobb-Douglas production functions R_{19} and R_{28} respectively.

Table 5.19. Production Elasticities of Different Inputs in Low and High Response Regions--Based on Cobb-Douglas Functions R_{19} and R_{28}

	Production Elasticities	
Input Variable	Low Response Region	High Response Region
X_1 Land (Acres)	.2761	.1030
X_2 Labour (Man-days)	.5023	.5002
X_3 Fertilizer (Rs.)	.1660	.1561
X_8 Draft Services (Rs.)	.1744	.3131
Sum of Elasticities[1]	1.1188	1.0724

[1] Null hypothesis that sum of Elasticities (ε), equals 1 was accepted at .01 per cent L.O.S.

Table 5.19 indicates that a one per cent increase in labour (*ceteris paribus*) could result in a .5 per cent increase in output in both regions. The fertilizer input in low and high response regions indicates output elasticities of .160 and .156 per cent respectively. As regards draft services, its production elasticities indicate that for the same proportional increase of this input (ceteris paribus) in the low and high response regions, the resulting proportional increase in output for the high response region would be more than twice that for the low response region.

(c) Intensities of Resource Use in Low and High Response Regions

For the purpose of evaluating intensity of resource application in paddy production and the resulting outputs in the two regions, per acre data were compiled in value terms. The results are presented in Table 5.20 below.

Table 5.20. Geometric Mean Levels of per Acre Inputs and Outputs on Paddy Farms in Low and High Response Regions--Incorporating Total Survey Data.

Output/Inputs		Low Response Region	High Response Region
Total output	(Rs.)	1,013.34	1,455.45
Labour	(Man-days)	55.96	54.92
Tractor Services	(Rs.)	71.22	113.02
Buffalo Services	(Rs.)	156.63	43.07
Draft Services[1]	(Rs.)	246.47	129.57
Fertilizers	(Rs.)	36.59	56.61
Agro-Chemicals	(Rs.)	16.50	12.00

[1] Includes both buffalo and tractor services.

The geometric mean value of total paddy output per acre in the high response region amounts to Rs.1455. The corresponding figure for the low response region is Rs.1013.34. When considering expenditures for buffalo and tractor services, it is clear that production in the high response region is more machine-oriented than in the low response region. Rice farms in the low response region used a total of 56 man days per acre. The corresponding value for the high response area is 55 man-days. A more intensive use of fertilizer is made by farmers in the high response region. Thus the higher productivity per acre in this region can be largely attributed to the intensive use of non-traditional inputs.

5. Resource Productivity Analysis at the District Level

As already indicated, initial selection of the farm sample in the present study was on a district basis. Therefore, measures of resource productivity in each of the districts would be useful in guiding resource allocation between districts. Inadequacy of observations in each district imposed a serious limitation on this type of analysis. Work was limited to estimating overall productivities of inputs and computing a productivity index value for each of the districts. In doing this, land was not included in the input cost assessments for the reason that it remained relatively fixed per farm within each district. Also fertility of land was thought to show little variability within each district. Therefore, the productivity index values afford district comparisons with regard to output and the more strictly variable inputs.

The productivity indices for included inputs (labour, draft service, fertilizer, agro-chemicals), are reported in column (6) of Table 5.21. Column (5) indicates the output/input ratios obtained by dividing total values of output by total values of inputs (geometric mean levels). Using this type of output/input ratio as a productivity measure implies a rather simplified linear production function with perfect substitution among factors of production. The productivity index is derived from the output/input ratios and represents deviations from the mean ratio for all districts.

Table 5.21. Overall Input Productivity Measures and Corresponding Levels of Input Application on Paddy Farms According to Districts

District	No. of farms	Geometric Mean Output (Rs.)	Geometric Mean Inputs[1] (Rs.)	Output Input Ratio	Productivity Index[2]
(1)	(2)	(3)	(4)	(5)	(6)
1. Polonnaruwa	30	6,724.62	2,679.20	2.510	.799
2. Hambantota	14	5,241.15	2,472.18	2.120	.408
3. Kurunegala	22	2,049.18	1,686.43	1.2151	-.497
4. Colombo	20	1,644.30	1,264.88	1.300	-.412
5. Kandy	21	1,023.22	722.61	1.416	-.296

[1] Excludes value of land. Includes labour, draft services, fertilizers and agro-chemicals.

[2] Arithmetic deviations from mean district output/input ratios.

Consequently, any positive index value is indicative of an overall input productivity level higher than the average for all districts. Similarly a negative index value shows productivity below the average.

The results of this analysis reveal interesting information. The highest inputs' productivity is shown by Polonnaruwa district while the lowest is shown by Kurunegala district. Kurunegala, Colombo, and Kandy districts show negative index values, indicating that they can be regarded as separately from Polonnaruwa and Hambantota. This supports earlier findings concerning regions, based on dummy variable and discriminant analyses. From the output/input ratios it is easy to see which districts show the greatest output increments per rupee of overall input expenditure. For example, Polonnaruwa has almost twice Colombo's output from a given input expenditure.

CHAPTER VI

SUMMARY, IMPLICATIONS AND RECOMMENDATIONS OF THE STUDY

This chapter deals with the summary and concluding remarks for the study. It is divided into three sections. Section A presents a summary account of the analysis, section B states the implications of results for policy decisions, and section C outlines potential areas for future research activity.

A. SUMMARY OF FINDINGS

The present study deals with rice production in major rice growing areas in Sri Lanka during the 1972-73 Maha (wet) season. Almost all the farmers in the survey areas adopted fertilizer-responsive high-yielding varieties of rice, yet were very dependent on traditional factors of production. Levels of fertilizer application on paddy farms were generally lower than recommended levels. No elaborate machines other than tractors were used, and production was relatively more dependent on an intensive use of labour. Although production techniques of farmers did not always reflect complete modernization, they were clearly indicative of the changing nature of agriculture. Thus, this study can be considered as an economic investigation of a major crop under a situation of changing subsistence agriculture.

The analysis was based on data from rice farms in the districts of Hambantota, Polonnaruwa, Kandy, Kurunegala and Colombo. The primary objective of the study was to determine resource productivities on the farms and to identify problems of resource allocation. The analytical method was based on production functions. The important findings of the study can be summarized as follows:

1. Production functions were estimated using two techniques, namely, the factor shares and least squares methods. The factor shares method did not yield completely satisfactory results due to inherently rigid assumptions in the method. Nevertheless, it provided a useful basis for comparison of results achieved from regression. Therefore, the least squares estimation technique became the primary research tool. The Cobb-Douglas production function was found to be the most suitable function form for the data. The estimated production function for total survey data is:

$$Y = 17.2187\, X_1^{.2570}\, X_2^{.5987}\, X_3^{.2030}\, X_8^{.1272} \qquad [6.1]$$

   where Y is the value of total output of paddy in Rupees, X_1 is land in acres, X_2 is total labour input in man-days, X_3 is the value of fertilizer input in rupees, and X_8 is the value of draft services in rupees.

2. Estimates of marginal value productivities (MVP's) of resources were computed from this function. All the MVP's were computed at geometric mean input levels per farm. The MVP of an acre of land was estimated at Rs.220.43; a man-day, Rs.8.89; a rupee of furtilizer input, Rs.3.89, and a rupee of draft services, Rs.0.99.

3. A comparison of the implicit prices (MVP's) and market costs (prices) of input resources suggested that typical farmers were concentrating on using land and draft power resources at efficient levels. However, fertilizer and labour inputs were shown to be not intensively enough used. In particular, fertilizer input showed marked under-utilization. The analysis also indicated that reallocation of existing farm resources could lead to increases in output. Shifting resources from draft power to fertilizer is a case in point.

4. Expansion path resource combinational relationships for the total farm sample production function were established as follows: $X_2 = 86.81\ X_1$; $X_3 = 179.47\ X_1$, $X8 = 112.28\ X_1$, where X_1, X_2, X_3 and X_8 refer to acres of land, man-days of labour, rupees of fertilizer and rupees of draft services, respectively.

5. The arithmetic mean levels of paddy production inputs per acre for all survey farms were as follows: labour 56.25 man-days; fertilizer, Rs.55.51; draft services, Rs.136.33; agro-chemicals, Rs.18.77. The geometric mean level of output per acre was 56.81 bushels whereas the arithmetic mean output per acre was 62.29 bushels. The estimated arithmetic mean per acre application of fertilizer from total value data, was 2.1 cwts. (mixed composition).

6. The production function for all survey data gave a total production elasticity measure of 1.186 for included variables.

This indicates the existence of approximately constant returns to scale in paddy farming in Sri Lanka.

7. From the production function for all survey data, determination of responses of output to variation in levels of input application reveals that one per cent changes (*ceteris paribus*) in land, labour, fertilizer and draft services inputs would result in .257, .599, .203 and .127 per cent changes in paddy output, repectively.

8. Allocation of total value product to each of the factor inputs showed that labour input accounted for half the total output, 50.6 per cent; while land, fertilizer and draft services accounted for 21.6, 17.0 and 10.8 per cent respectively.

9. Average apportioned productivities of inputs were also determined. These values were Rs.185.50 per acre of land; Rs.7.49 per man-day; Rs.3.28 per rupee of fertilizer input; and Rs.0.83 per rupee of draft services input.

10. Attempts were also made to identify productivity regions within the area providing total farm sample data. Two regions indicating different resource productivities were identified. They were termed low response and high response regions. The former included Polonnaruwa and Hambantota districts, while the latter included Kurunegala, Colombo and Kandy districts. The production function estimates for the two regions were:

(i) Low response region,

$$Y_L = 23.289\, X_1^{.2761}\, X_2^{.5023}\, X_3^{.1660}\, X_8^{.1744} \qquad [6.2]$$

(ii) High response region,

$$Y_H = 15.059\, X_1^{.1030}\, X_2^{.5002}\, X_3^{.1561}\, X_8^{.3131} \qquad [6.3]$$

where, the variables have the same definitions as given for production function [6.1].

11. MVP estimates for inputs at geometric mean levels in the two regions showed notable differences in the case of draft power. The relevant value for the low response region was Rs.0.59 per rupee of input, while in the high response region the comparable value was Rs.3.20. Typically this suggests an over use in the low response region and an under use in the high response region. The MVP's of labour and fertilizer inputs in the high response region were substantially higher than those in the low response region. The MVP of land was greater in the low response region than in the high response region.

12. Expansion path equations were derived from each regional production function. While they provide interesting comparisons with the previously estimated expansion path equation for the total farm sample function, the comments in the text regarding the use of all these relationships should be duly noted.

13. Comparison of intensities of resource use per acre in the two

regions indicated that higher levels of tractor services and fertilizers have been used by farmers in the high response region. On the other hand, higher levels of labour, buffaloes and chemicals have been used on farms in the low responsive region.

14. Increasing returns to scale were indicated by the included variables for both low and high response regions: 1.1188 and 1.0724 respectively. Since these values do not statistically differ from 1, near constant returns to scale may be said to apply.

15. Comparisons of overall resource use (except land) in different districts was undertaken using a productivity index approach. The results showed that the highest productivity of inputs was in Polonnaruwa, whilst the lowest was in Kurunegala. The productivity indices of farm inputs in Colombo and Kandy districts were not substantially different from that of Kurunegala. In Hambantota district, the resource productivity index was close to that of Polonnaruwa.

B. IMPLICATIONS AND POLICY RECOMMENDATIONS OF THE STUDY

1. Need for Productivity Increases in the Paddy Sector

The need to increase productivity of resource input investment in Sri Lanka's paddy sector requires immediate attention in any development policy for increasing the domestic output of rice. Support for this argument is also given by the following discussion.

Despite many attempts to increase production, total domestic output of rice still accounts only for about 60 per cent of total consumption. Nevertheless, there has been a significant increase in domestic paddy output over the past three decades. Total home production rose from 31.3 million bushels in 1956-57 to 48.1 million bushels in 1961-62, representing an increase of 70 per cent over a period of six years. Two major reasons for these output increases can be given. Firstly, expansion of land under cultivation has occurred and secondly, per acre yield increases have been achieved.[1] Before 1965, land expansion played a major role in the national increase in rice output. For instance, from 1957-65 the increase in net area harvested was 29 per cent, while yiëlds increased by only 14 per cent in the same period. Now that expansion of land under cultivation has slowed up yield increases become a crucial factor in increasing domestic rice production.

The magnitude of the desired output increase in the paddy sector has been estimated by Karunatilaka.[2] On the assumption of a net annual population increase of 2.5 per cent per annum, with no changes in existing per capita consumption, he estimated that rice requirements to meet this rate of increase can be produced on the existing acreage only if 1.5 extra bushels per acre are forthcoming every year. However, during

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[1] P.C. Bansil, "Impact of Food Policy on Agricultural Development in Ceylon," Indian Jour. Agric. Econ.: 21, 1966, No. 1, p. 240.

[2] H.N.S. Karunatilaka, Economic Development in Ceylon, New York, Praeger Publishers, Inc., 1971, p. 312.

the period 1955-65 the realized increase in national per acre yield was only about .9 bushels per annum.

The argument for raising output through land productivity increases rather than traditional acreage increases, is again supported by a consideration of the large investments made on certain major irrigation projects. It seems logical to say that the pay-off from such expensive land expansion policies will be low so long as the less intensive traditional production techniques are used. Therefore, it follows that the fundamental objective of policy in the future should be to increase rice production more through intensified use of resources and less through land expansion.

2. Output Expansion Through Appropriate Product Pricing

The marginal value productivity of an input is dependent on the output price, and thus, by suitable manipulation of output price, the level of input application by farmers can be changed. Since the paddy price in Sri Lanka is solely determined by central authority--the paddy marketing board--the price can easily be used as a powerful tool for motivating farmers to increase their output through employment of more resources.

Furthermore, a number of major economic studies have shown empirical evidence for indicating that economic incentive is a strong motivating factor responsible for spreading new innovations in agriculture.[3] It has

[3] Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," in Readings in the Economics of Agriculture, Illinois, Richard D. Irwin, Inc., 1969, pp. 221-243.

also been proved that farmers, even in a subsistence economy, behave as "economic-men" and are quite responsive to economic incentives such as prices.[4,5] Therefore, it would appear that there exists a strong case for re-examining the efficiency of the guaranteed price mechanism for increasing national paddy output.

3. Increased Supplies of Fertilizer

Fertilizer input is one of the "essentials" in a package of non-traditional inputs that play a crucial role in raising paddy output. This is evident from the analysis undertaken and it is indicated by the marginal and average productivity estimates and elasticity coefficients. The fertilizer MVP estimate at the geometric mean input level for total survey data, showed that for an additional rupee of fertilizer the output was increased by Rs.3.98. This indicates a gross under-utilization of fertilizer, far below the economic optimum. The analysis also shows that, even if the existing 50 per cent subsidy on fertilizer is removed, it is still economically advantageous for many farmers to apply more fertilizer.

This finding in the light of heavy public expenditure on subsidizing the input, logically raises the problem whether such a subsidy is, in fact, a necessity. If the subsidy is done away with, it would lead to a higher input price. Such a price increase would have two important

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[4] Welsch E. Delane, "Responses to Economic Incentives by Abakaliki Rice Farmers in Eastern Nigeria," Jour. Farm Econ., 47, 1965, pp. 900-914.

[5] Jere R. Behrman, "Price Elasticity of the Marketed Surplus of a Subsistence Crop," Jour. Farm Econ., 48, 1966, pp. 875-892.

consequences for fertilizer use. Firstly, it would reduce the optimum level of application which would no doubt restrict output. Secondly, it would also reduce farmers' "accessibility" to the input. The latter has particular significance in a peasant farming system where ready cash is generally scarce. Therefore, even if removal of the fertilizer subsidy still leaves the input profitable to use at the existing level of application, it could still affect the level of fertilizer application purely through the "inaccessibility" to cash factor. Therefore, whatever price changes are made for fertilizer, it is necessary that the policy makers be aware of the twin problems.

4. Expansion of Farm Credit Facilities

The results of the study point to disequilibria in resource application. This is evident with respect to both total data and disaggregated data. Achieving the correct allocation of application of resources depends on capital availability. Therefore, the observed resource imbalances seem to be suggestive of a capital rationing situation in paddy farming. Although the need for capital to increase output has been recognized and remedial measures taken over a fairly long time, the results of this study would indicate that the problem is still serious. The modernization of paddy farming requires increased adoption of a number of non-traditional intensively used inputs, which implies increased capitalization of farms.

Although a full discussion of farm credit expansion will not be entered into, a major aspect of the subject that seems to have been largely overlooked and requires careful attention concerns the risk side of paddy farming. The argument can be summarized briefly as follows: development necessitates new techniques and inputs; these inputs are viewed by farmers as risky from the standpoint of results; farmers are risk averse. Therefore, if inputs are to be obtained through credit, risk perception is an important impediment to expanding farmer use of credit schemes. Hence, expansion of such schemes need to be complemented by other programmes such as crop insurance[6] and adequate irrigation facilities.

5. Investments in Farmer Education

Though not explicitly arising from the current study, evidence suggests that farmer education is one of the high pay-off inputs in farm production.[7] Since the production situation in the study was characteristic of a changing agriculture, the existence of resource-use dis-equilibriam may be attributed, at least in part, to lack of information. This would particularly apply to the use of modern inputs such as new rice varieties and new types of fertilizer, which need considerable managerial ability for deriving optimal results.

The evidence for a relationship between increased agricultural production and farmer education has been directly shown by a number of

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[6] Nimal Sanderatna, "Using Insurance to Reduce Risk in Peasant Agriculture: Guidelines from Sri Lanka Experience," Teaching Forum, ADC Publication No. 43, June, 1974.

[7] An interesting discussion of this subject is given by T.W. Schultz, The Economic Value of Education, New York, Columbia University Press, 1963.

studies. Their estimates usually indicate educational benefits that are high by most standards. Such returns to education arise basically from the increasing quality of labour in farm production. In the light of this evidence it is reasonable to suggest that an important means of increasing productivity in Sri Lanka's paddy farming, is to make increased investments in educating rural farmers[8] in the modern techniques of rice production.

To conclude this section it can be stated that it is not sufficient just to add more traditional input factors to increase domestic paddy output. What is needed also is better seed varieties along with adequate supplies of fertilizer and additional irrigation, complemented by a price and cost setting and an educational environment would make these worth while.

C. AREAS OF FURTHER RESEARCH

In general the issues that have been considered in the above sections seem to serve as a broad framework for a future research agenda, aimed at increasing productivity in the rice sector. In addition, certain specific areas requiring research attention are outlined below.

1. Labour Use in Paddy Cultivation

About one-half of the rural population in Sri Lanka is directly dependent on paddy cultivation. Under a present increase of population

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[8] F. Welsch, "Education in Production," Jour. Pol. Econ. 78, 1970, pp. 35-59.

of 2.1 per cent per annum, a mounting pressure on arable land in rural areas is exerted which leads to rural unemployment. Thus, studies on different aspects of labour use in rice farming are most important, not only in the context of paddy production, but also on the general problem of unemployment in peasant agriculture.

An important area of research along the lines suggested concerns the labour-use cycle during the crop year. Information here would help assess the seasonal demands for family and hired labour in paddy cultivation. This knowledge is important in view of the widely varying labour requirements at particular stages of the rice crop and the involvement of farm families in off-farm employment. Studies on seasonal demand for labour use in production can also yield useful information relating to mechanization of paddy cultivation.

Another useful area for study would concern the concepts of rural unemployment and disguised unemployment.[9] Furthermore, a notion is often held by economists concerned with subsistence agriculture, that zero marginal productivity of agricultural labour occurs in this sector, e.g., " . . . commonly categorized feature of the dual economy [in Sri Lanka] is the zero marginal productivity of labour . . . this perhaps is the basic economic criterion on which distinctions can be made between traditional and modern sectors."[10] If true this statement means that some agricultural workers could be transferred to other tasks without diminution

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[9] B. M. Mahajan, "Population Problem Reconsidered," Econ. Affairs, 10, January, 1965, pp. 73-82.

[10] Karunatilaka, op. cit., p. 23.

of agricultural output and new entrants to agriculture would make no productive contribution. But empirical results from the present study provided substantial evidence to show that the marginal productivity of rural labour is positive (in fact quite high). In addition the results did not indicate the presence of disguised unemployment in the paddy sector. Further evidence for the absence of disguised unemployment in certain areas is the seasonal immigration of farm labour, e.g., to Hambantota and Polonnaruwa districts from other areas. Many of the disagreements concerning problems of disguised unemployment stem from confusion between seasonal unemployment and disguised unemployment. A count of idle work-days per year tells us nothing about the superfluity of workers on a year-round basis.

2. Implications of Rice Policy on the Domestic Paddy Sector

The fundamental objectives of the Sri Lanka government's rice policy may be summarized as follows: (1) to keep farm paddy price high, (2) to maintain low consumer prices, and (3) to reduce imports. Although no hard empirical evidence is available, examination of some of the policy measures suggests that they may sometimes hinder the achievement of goals. Such problems need to be studied to determine alternative remedial measures. In broader terms, studies should evaluate specific policy objectives with respect to past achievements, inter-relationships, and interactions between different goals and their relationship to decision variables. Resulting information would be very useful for recommending and achieving suitable policy measures.

A broad group of economic problems arises from Sri Lanka's traditional "cheap food" policy. The producer and consumer subsidies on rice during 1964 amounted to Rs.446.9 million, approximately 25 per cent of total annual government revenue.[11] Aside from direct effects artifically lowering the price of rice to consumers, the subsidies' impact on local production would also have been substantial. Studies are needed to elucidate such effects. Another important area for research is the efficiency of the government guaranteed price system (GPS), introduced for increasing domestic rice production. With regard to the contribution of GPS to paddy output, Karunatilaka[12] comments that " . . . it has not provided a very significant spur to accelerated production." Bansil,[13] in a detailed study on the same aspect concludes that " . . . perhaps we would not be far too wrong to conclude that GPS has miserably failed to achieve its objective of increasing paddy production. If at all it might have served as a disincentive. . . . The GPS would then appear to have not only harmed the interest of paddy, but practically the whole of the peasant agricultural sector."[14] This evidence seems to indicate the potential nature of the problem.

The impact of food grain imports, including food aid, on the prices and domestic supply of paddy also needs considerable attention.

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[11] Bansil, op. cit., p. 240.

[12] Karunatilaka, op. cit., p. 313.

[13] Bansil, op. cit.

[14] Ibid., p. 245.

Schultz[15] in discussing Indian agriculture, pointed out that the effects of PL 480 imports upon the agriculture of a recipient country were likely to be adverse because of a fall in the prices of domestic agricultural products, thus reducing the incentive to maintain or expand the agricultural sector. The dependence on cereal imports in Sri Lanka is substantially large and it is necessary to test the above hypothesis using systematic research methods.

3. Studies on Economic Responses from the Farmer

A number of recent economic studies have shown evidence of economic influences receiving measurable responses from subsistence farmers. Generally, however, there seems to be a tendency among policy makers to think of the subsistence farmer as being lazy and unresponsive to price relationships. Farmers are often thought to be irrational in their rejection of innovations; frequently they are blamed for being a hinderance to modernization.

Therefore, research efforts are necessary to establish the validity of these attitudes towards peasant farmers in Sri Lanka. Information from such studies would be helpful in perfecting the incentive framework and improving the efficiency of the price mechanism for raising farm output. Under usual circumstances, product price can act as an indicator of profit in farming. But in a subsistence economy the measure of "profitability" may not depend so much on product price. Therefore, research

15 T. W. Schultz, "Value of U.S. Farm Surpluses to Under-developed Countries," Jour. Farm Econ., 42, 1960, pp. 1019-30.

should be conducted to determine the merits of economic incentives and the causes of motivation.

Economic aspects of innovation among paddy farmers have so far been a neglected area of study. Risk and uncertainty influences on farmers seem to have an important bearing on the acceptance of new innovations. Identification of the relationship of risk and uncertainty to innovative and adoption behaviour of farmers is important in the diffusion of new technologies.

Other factors such as institutional and socio-cultural forces also seem to have significant influences on modernization of the paddy farming sector. The institutional-cultural matrix, within which farmers operate, has a considerable effect on their economic decisions and hence it needs understanding. The land tenure system is a good example of an economic set of arrangements in an institutional and social framework. Much can be learnt about the efficiency of such practice by well-designed studies. And so the recommended list of research studies grows. Enough, however, has been said to draw the discussion to a close. The study findings appear pertinent to Sri Lanka's problems in rice production. On the other hand they only serve to raise many more questions.

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APPENDIXES

1 - 8

APPENDIX I

PROCEDURE FOR CALCULATING MVPs

MVP is defined as the addition to total revenue by a marginal unit of input. In a linear production function of the form $Y = a+b_1X_1+b_2X_2+\ldots b_nX_n$ where, Y is the total value product and $b_i (i = 1,2,\ldots n)$ are the regression coefficients, the MVP of each resource input is given by its regression coefficient. However, in a log-linear function such as $Y = aX_1^{b_1}X_2^{b_2}\ldots X_n^{b_n}$, MVPs are no longer given by the logarithmic function regression coefficients. The coefficients in this case represent the elasticities of output with respect to particular inputs. Hence the MVP of an input X_1 can be calculated with regard to mean input levels. Where $\bar{Y}$ refers to the estimated mean output and $\bar{X}_i$s refer to mean source inputs.

i.e., $$MVP_{X_1} = \frac{\partial\bar{Y}}{\partial\bar{X}_1} = b_1 a\bar{X}_1^{b_1-1}\bar{X}_2^{b_2}\ldots\bar{X}_n^{b_n} \qquad [1]$$

$$= \frac{b_1 \cdot \bar{Y}}{\bar{X}_1} \qquad [2]$$

Thus, the above value of MVP depends on the mean values of X's used. But MVPs can also be calculated at geometric mean levels of inputs farm inputs so as to represent the typical situation.[1]

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[1] Geometric mean level of an input is computed by taking the antilogarithm of the arithmetic average of the logarithms of the individual observations. Further details regarding the geometric mean are given in F. E. Croxton and D. J. Cowden, Applied general Statistics (New York: Prentice Hall, Inc., 1955), 2nd ed.

APPENDIX 2

COMPUTATION OF RETURNS TO SCALE

The Returns to scale in Production are indicated by the value obtained from summation of output elasticities of all inputs. This value is also referred to as the function coefficient (ε) and it indicates the proportional change in output resulting from a simultaneous 1 per cent change in all inputs.[1] This can be seen as follows:
Given the production function as,

$$Y = f(X_1, X_2, \ldots X_n) \qquad [1]$$

the output elasticity ε_i of i-th input is, by definition,

$$\varepsilon_i = f_i \frac{X_i}{Y} \quad (i = 1, 2, \ldots n) \qquad [2]$$

where,

$$f_i = \frac{\partial Y}{\partial X_i} \qquad [3]$$

Taking the total differential of the production function [1] we have,

$$dY = \sum_{i=1}^{n} f_i \cdot dX_i = \sum_{i=1}^{n} X_i f_i \frac{dX_i}{X_i} \qquad [4]$$

or,

$$\frac{dY}{Y} = \sum_{i=1}^{n} \cdot f_i \frac{X_i}{Y} \frac{dX_i}{X_i} \qquad [5]$$

Let all inputs be increased by a constant proportion $\frac{dk}{k}$; then for all inputs X_i,

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[1] For details refer C. E. Ferguson, Microeconomic Theory (Illinois: Richard D. Irwin, Inc., 1972), pp. 161-64.

$$\frac{dX_i}{X_i} = \frac{dk}{k}$$

Then, dividing equation [5] by the constant $\frac{dk}{k}$ we get,

$$\frac{dY}{Y} \div \frac{dk}{k} = \sum_{i=1}^{n} f_i \frac{X_i}{Y} \qquad [6]$$

$$= \sum_{i=1}^{n} \varepsilon_i$$

But by definition the left hand term in equation [6] equals ε, the function coefficient,

therefore $$\varepsilon = \sum_{i=1}^{n} \varepsilon_i$$

This shows that the function coefficient (ε) is simply the sum of output elasticities of individual inputs. We say when $\varepsilon = 1$ constant returns to scale exist; $\varepsilon > 1$ increasing returns to scale exist; and $\varepsilon < 1$ decreasing returns to scale exist.

APPENDIX 3

METHOD OF DISTRIBUTING TOTAL PRODUCT TO INDIVIDUAL FACTORS OF PRODUCTION

If a function is homogeneous of degree r (= function coefficient) then by Euler's theorem it can be shown that,[1]

$$\frac{\partial Y}{\partial X_1} X_1 + \frac{\partial Y}{\partial X_2} X_2 + \ldots \frac{\partial Y}{\partial X_n} X_n = rY \qquad [1]$$

Therefore,

$$Y = \frac{\partial Y}{r\partial X_1} X_1 + \frac{\partial Y}{r\partial X_2} X_2 + \ldots \frac{\partial Y}{r\partial X_n} X_n \qquad [2]$$

Hence, this proves that the amount contributed to the gross value of production by an individual factor of production is equal to its marginal product multiplied by the level of application of the input and divided by the degree of homogeneity.

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[1] For more details see, C. E. Ferguson, Microeconomic Theory (Homewood, Illinois: Richard D. Irwin, Inc., 1972), pp. 411-412; and A. C. Chiang, Fundamental Methods of Mathematical Economics (London: McGraw-Hill Book Co., 1967), p. 376.

APPENDIX 4

COMPARATIVE DATA ON SRI LANKA'S MAJOR CROPS 1967; ACREAGE, OUTPUT AND EXPORTS

Product	Acreage ('000 Acres)	Total Output Volume	Value of Exports (Million Rs.)	Value of[d] Total Output (Million Rs.)
1. Tea	599	486.7[a]	1,061	1,074.4
2. Rubber	475	288.8[a]	337	326.3
3. Coconut	1,100	2,600.0[b]	94	260.0
4. Rice	1,332	41.4[c]	-	579.6
Total	3,506	-	1,492	2,240.3

[a] Million lbs.

[b] Million nuts.

[c] Million bushels.

[c] Value of exports plus Colombo market value of volume not exported.

Source: P. Richards and E. Stoutjesdijk, Agriculture in Ceylon until 1975, Development Centre Studies, OECD, Paris, 1970.

APPENDIX 5

COMPARATIVE DATA ON SRI LANKA'S MAJOR CROPS, 1967; EMPLOYMENT AND VALUE ADDED

Product	Value of Total Output (Million Rs.)	Value added (Million Rs.)	Estimated Employment (Thousands)	Value added per worker (Rs.)
1. Tea	1,074.4	846.6	658	1,286.6
2. Rubber	326.3	273.5	223	1,226.5
3. Coconut	260.0	206.5	88	2,346.6
4. Rice	579.6	377.1	666	566.2
Total	2,240.3	1,703.7	1,635	1,042.0

Source: P. Richards and E. Stoutjesdijk, Agriculture in Ceylon until 1975, Development Centre Studies, OECD, Paris, 1970.

APPENDIX 6

DISTRIBUTION OF SAMPLE FARMS ACCORDING TO DISTRICTS

District	No. of Farmers
1. Polonnaruwa	30
2. Hambantota	14
3. Kurunegala	22
4. Colombo	20
5. Kandy	21
Total	107

APPENDIX 7

SIMPLE CORRELATION COEFFICIENTS[a] FOR LOGARITHMICALLY TRANSFORMED VARIABLES INCLUDED IN PADDY REGRESSION ANALYSIS--TOTAL FARM DATA--LOW RESPONSE REGION (63 FARMS)

Farm Variable[b]	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Y Output (Rs.)	1.00								
X_1 Land (Acres)	.72	1.00							
X_2 Labour (man-days)	.88	.71	1.00						
X_3 Fertilizer (Rs.)	.76	.69	.29	1.00					
X_4 Machinery Services (Rs.)	.52	.70	.32	.81	1.00				
X_5 Animal Services (Rs.)	.68	.48	.76	.74	-.83	1.00			
X_6 Agro-chemicals (Rs.)	.55	.54	.64	.63	.20	.76	1.00		
X_7 Seed Material (Rs.)	.85	.74	.88	.78	.24	.74	.57	1.00	
X_8 Draft Services (Rs.)	.69	.71	.67	.64	.52	.69	.58	.64	1.00

[a] $H_o : \rho = 0$, rejected if calculated $r > .190$ (.05 L.O.S.); $r > .248$ (.01 L.O.S.).

[b] For definition of variables, see Chapter IV.

APPENDIX 8

SIMPLE CORRELATION COEFFICIENTS[a] FOR LOGARITHMICALLY TRANSFORMED VARIABLES INCLUDED IN PADDY REGRESSION ANALYSIS--TOTAL FARM DATA--HIGH RESPONSE REGION (44 FARMS)

	Farm Variable[b]	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Y	Output (Rs.)	1.00								
X_1	Land (Acres)	.78	1.00							
X_2	Labour (man-days)	.81	.62	1.00						
X_3	Fertilizer (Rs.)	.86	.64	.38	1.00					
X_4	Machinery Services (Rs.)	.39	.78	.42	.69	1.00				
X_5	Animal Services (Rs.)	.42	.47	.73	.68	-.79	1.00			
X_6	Agro-chemicals (Rs.)	.62	.68	.79	.74	.24	.66	1.00		
X_7	Seed Material (Rs.)	.74	.34	.64	.79	.20	.64	.62	1.00	
X_8	Draft Services (Rs.)	.69	.81	.67	.68	.61	.72	.69	.78	1.00

[a] $H_o : \rho = 0$, rejected if calculated $r > .190$ (.05 L.O.S.); $r > .248$ (.01 L.O.S.).

[b] For definition of variables, see Chapter IV.