TECHNICAL EFFICIENCY IN RICE PRODUCTION: A Farm-Level Study on Tamil Nadu

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE
AWARD OF THE DEGREE OF
MASTER OF PHILOSOPHY
IN APPLIED ECONOMICS OF THE
JAWAHARLAL NEHRU UNIVERSITY, NEW DELHI

MARGARET ANTONY

CENTRE FOR DEVELOPMENT STUDIES
THIRUVANANTHAPURAM

1998

DECLARATION

July 18, 1998.

I hereby affirm that the research for this dissertation titled ***"Technical Efficiency in Rice Production: A Farm-Level Study on Tamil Nadu"*** *being submitted to the Jawaharlal Nehru University for the award of the Degree of Master of Philosophy in Applied Economics, was carried out entirely by me at the Centre for Development Studies, Thiruvananthapuram.*

Margaret Antony

Certified that this dissertation is the bonafide work of Margaret Antony. This has not been considered for the award of any other degree by any other University.

K. Narayanan Nair
Fellow
(Supervisor)

Chandan Mukherjee
Director

CENTRE FOR DEVELOPMENT STUDIES
Thiruvananthapuram

When dark clouds gather
And raindrops fall
In storms of life,
The bright promises of the Archer
Span like his bows
From cloud to cloud of the saddened heart.
(Edward A. Gloeggler)

....So thank him without measure
For his blessings showered down
That fill our lives with pleasure
Till at last we are homeward bound.
(Albert N. Theel)

ACKNOWLEDGEMENT

It is with deep gratitude that I place on record my acknowledgement to all those who have helped me during the course of this study and have stood by me in the most trying times.

I am greatly indebted to my supervisor, Dr. K. Narayanan Nair, for his most inspiring encouragement, concern and help. I thank him for the patience shown. His trust and confidence in me helped to keep my spirits high even in the most unfavourable circumstances.

Words, I am sure, would fail to express the deep gratitude I owe to Dr. Anand Raj who had painstakingly gone through the entire draft at the crucial hour. I thank him deeply for the valuable suggestions, for helping with the econometric clarifications and for the editing which gave this work the final shape.

I thank Dr. Indrani Chakraborthy for initiating me into this line of research.

I thank Albert Christopher Das for providing me with the data and other information relating to the Cost of Cultivation Data. To the Cost of Cultivation Department, New Delhi, I express my gratitude for granting me the permission to use the data. M.R. Anand and Sudha are gratefully acknowledged for seeing to it that I had no problem in getting the permission.

I express my sincere gratitude to Dr. U. Shankar, Dr. A. Vaidyanathan, Dr. K.L. Krishna, Dr. K. Nagaraj, Dr. K.R. Shanmugham, Dr. Maithily, Dr. Janakarajan, Dr. Sarthi Acharya and Dr. R. Rukimani for their professional support at various stages of this work.

If it were not for Lekha and Lalu, this work would have been unthinkable of, perhaps. It was at the most crucial time that Lekha intervened and Lalu helped me retrieve the data used in the present study. I express my indepth gratitude to them. I remain grateful to Lekha and Pinaki for all help. I express my deep sense of gratitude to dear 'Ummachi' who has always been wishing that all is well with me.

I express my gratitude to Dr. Mohanan Pillai for all his good wishes and concern and above all for his patience, trust and encouragement at the crucial hour.

Dr. K. K. Subramaniam had thrown in many useful tips in the most casual manner for which I am really grateful.

I thank Dr. Sunil Mani for lending me the LIMDEP manual. To Dr. Panda I express my gratitude for clarifying my doubts and for all the encouragement and concern shown. Dr. U.S. Mishra and Dr. Mala have also helped me in clearing my doubts for which I am grateful.

I thank Phil Roy for all his patience and concern and all the office and library staff for the help and kindness extended. It is with deep gratitude that I acknowledge Gopakumar and Shoba chechy who had helped me save a lot of time in locating the books. I express my gratitude to Soudhamani who has been very kind and understanding.

Discussions with seniors had proved very useful. Here, I am greatly indebted to Binoy and Hari Kurup on whom I have relied the most. I thank Tara, Rajkishan, Binu, Sanjith, Suresh and

Meena for their professional help at various stages of this work. I express my indepth gratitude to Sam and Azeez for all the help and strain taken in helping me with the final printout. All help received from Charvak, Sunny, Prasad, Deepa, Bindhu and Jyothi are gratefully acknowledged.

Words fail to acknowledge dear 'Music Mami' whose soothing music helped to ease a lot of tension. I acknowledge my classmates with whom I have shared many a good moment and all the others in the campus who have been most understanding. I gratefully acknowledge Kavitha, Margarita, Ayhan and Ronke for their kindness and concern.

To my dear parents I remain most grateful for all the innumerable wonderful things that have been said and done. I express my indepth gratitude to Anu chechy and Eisen chetan for all help and care. To my family I owe a lot for all the love, concern, inspiration and prayers that have worked miracles for me. I sincerely regret not having been able to spend as much time as I would have loved to with little Divya who has brought into our lives much love and fun.

Satyameva Jayate!

Thiruvananthapuram. **Margaret Antony**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

"Farmers the world over, in dealing with costs, revenues and risks, are calculating economic agents. Within their small allocative domain they are fine-tuning entrepreneurs, turning so subtly that many experts fail to see how efficient they are".

(Schultz, T. W., 1978)

INTRODUCTION

Technology has played a crucial role in increasing agricultural production, especially foodgrain production, in India. High yielding varieties (HYV) of seeds were introduced in the country in the late sixties with the view to increase food security (Kumar, 1996; Selvarajan and Ravishankar, 1996). The introduction of the new seed technology was accompanied by the complementary inputs like chemical fertilizers, pesticides, weedicides and assured irrigation through development of irrigation infrastructure. This technological intervention strategy brought about a significant shift in the nature of cultivation practices as the new strategy necessitated an input mix different from that of traditional crops. The success of this strategy appears to depend as much on adaptation and assimilation as on the rate of diffusion at farm level. The adaptation of technology may be location-specific, whereas the assimilation of technology may depend upon the individual farmer's absorptive capacity and willingness to adopt (Andrew, 1996; Wilson, 1996). The extent of adaptation and assimilation of agricultural technology could vary among regions (Bhalla & Tyagi, 1989a; Bhalla and Tyagi, 1989b; Sawant and Achutan, 1995; Kumar and Rosegrant, 1994; Sawant, 1997; Singh et al, 1997) and among farms within regions. Accordingly, the consequent input-mix would also be different among regions and farms within regions. The different input mix at farm level for a given technology may possibly result in different sub-optimal levels of maximum possible output.

In the context of evaluating the impact of agricultural technology on farm output and income, the pertinent question that arises, therefore, is regarding the response of the farming community to the introduction of HYV. Here, decision-making at the farm-level assumes importance. Decision-making of a farmer relates to his ability and willingness to achieve the maximum possible output with a given set of inputs[1]. This phenomenon can be understood with the help of the concept of economic efficiency in terms of its components - technical efficiency and allocative efficiency. Quantification of these measures at the farm level would facilitate comparison of production performance across farms and enable the identification of factors causing variations in efficiency across farms. Moreover, the policy implications of such analyses for the improvement of efficiencies have significant macroeconomic significance[2]. It is in this context that the present study on the technical efficiency in rice production in Tamil Nadu is carried out.

1.1 The Rice Economy in Tamil Nadu

Paddy is the most important crop in Tamil Nadu agriculture, accounting for 30.9 per cent[3] of the total cropped area. The state has recorded one of the highest levels of productivity in India: about 2.5 tonnes per hectare[4] and has maintained a relatively steady trend in the production as well as yield.

---

1 *Nirmala, 1992.*

2 *Kalirajan and Shand, 1994.*

3 *Source: Season and Crop Report, 1992-93.*

4 *Nirmala, 1992.*

Considering the fact that Tamil Nadu lies in the low-to-moderate rainfall region (500-1000 m.m) within India and that its soil is deficient in organic matter, nitrogen and phosphoric acid, the state's growth rate of paddy production is not unimpressive[5].

Although the state has witnessed significant increase in productivity, especially after the mid sixties, there has been a declining trend in the area under the crop since the eighties. Inspite of the decline in area, production has been maintained at relatively high levels, through yield improvement. While the impressive expansion in rice production during the nineteen fifties has been attributed to the expansion in area rather than increase in yield, the growth in output since the mid-sixties is attributed to improved productivity (Nirmala, 1992; Selvaraj et al, 1998; Nagaraj, 1998). The yield and production of rice which were only 1050 kg per hectare and 33.3 lakh tonnes in 1959-60 respectively, rose to the level of 1899 kg per hectare and 46.2 lakh tonnes in 1970-71 and to 4933 kg per hectare and 115.28 lakh tonnes in 1994-95. This phenomenal increase in the productivity and production of rice, termed as the `rice revolution', has been made possible through the widespread cultivation of high-yielding varieties, expansion of irrigation facilities, increased use of fertilizer and higher profitability (Nirmala, 1992; Selvaraj et al, 1998)

There has been a significant increase in the coverage of area under high-yielding varieties since the launch of the Green Revolution Strategy in the mid sixties (Chinnappa, 1977; Farmer et

---

5 *Mahalingam, 1987*

al, 1977; Harriss, 1977). It increased from seven per cent of the area under the crop in 1966-67 to 92 per cent by 1994-95[6]. The use of inputs per hectare has also shown significant increase since the mid-sixties. The intensification of inputs has, however, been accompanied by rising cost of production. A comparison of the cost of cultivation in Tamil Nadu with a number of other rice growing states reveals that it is relatively higher in Tamil Nadu (Acharya, 1995). This is, however, not in consonance with the general pattern which shows crops with high (land) productivity to also have low unit cost (Acharya, 1995). This point may be substantiated by the examples of wheat in Punjab which has the highest land productivity and lowest unit cost; cotton in Maharashtra which is least productive and most expensive; and sugarcane in Karnataka which has high productivity and least cost[7]. One important aspect that needs to be examined to gain insight into the relatively high cost in the face of rising land productivity is the technical efficiency in input-output relations which forms the focus of the present study.

1.2 Objectives and Scope of the Study:

The study makes a cross-sectional analysis of technical efficiency in rice production, at the farm-level, for the state of Tamil Nadu during the agricultural year 1992-93. More specifically, the objectives of the study are the following:

---

6 *Source: Tamil Nadu - An Economic Appraisal 1995-96.*

7 *Acharya, 1995.*

1. To estimate the farm-specific levels of technical efficiency in paddy production in the state for the two main agricultural seasons namely, kharif and rabi, and

2. To examine the farm-specific factors accounting for inter-farm differences in technical efficiency levels.

The study makes use of the production frontier methodology in measuring the technical efficiency of farmers belonging to different size classes of land holdings. The reasons for concentrating only on the technical efficiency aspect of economic efficiency may be made clear. Of the two components, measurement of technical efficiency assumes greater importance in the context of overall economic efficiency. In a recent study Kalirajan and Shand (1994) demonstrated that the causality runs from technical efficiency to allocative efficiency. It implies that an understanding of technical efficiency would provide more insights into the overall economic efficiency at farm level. Moreover, the measurement of crop-specific allocative efficiency requires crop-specific input prices paid which the data on costs of cultivation does not provide. Keeping these issues in view, the present study concentrates only on the technical efficiency aspect of economic efficiency.

1.3 The Data Source

The analysis has been carried out by making use of farm-level data collected by the Directorate of Economics and Statistics (DES), Government of India under the Comprehensive Scheme for the study of cost of cultivation of principal crops for the state of Tamil Nadu.

Data relating to cost of cultivation surveys under the Comprehensive Scheme is collected with the help of various agricultural universities which are called Implementing Agencies. These Implementing Agencies collect data from sample holdings in the State of their assignment following cost accounting method. The present design of the survey under the Comprehensive Scheme is stratified three stage random sampling with tehsil as the first stage unit, village/cluster of villages as the second stage unit and an operational holding within the cluster as the third and ultimate stage unit. Each State is divided into homogeneous agro-climatic zones, based on cropping pattern, soil types, rainfall, etc. The primary sampling units (tehsils) are allocated to different zones in proportion to the total area of all the crops covered by the study. The primary sampling units are selected in each zone (stratum) with probability proportional to the area under the selected crops, and with replacement. Within each tehsil, the village/cluster is also selected following the same procedure. In each selected village/cluster, all the operational holdings are enumerated or classified according to 5 size classes, the class limits being fixed uniformly for all villages/clusters. These size classes are Marginal (upto 1 hectare), Small (1 to 2 hectares), Semi-medium (2 to 4 hectares), Medium (4 to 6 hectares) and Large (more than 6 hectares). In each size class, two holdings are selected by simple random sampling, without replacement. However, if in any village/cluster, a particular size class does not contain even two holdings, more holdings are selected from adjacent size-classes to make up the deficit[8]. The list of the zonal division

---

8 *Ram, (Undated).*

and of the tehsils and villages selected under the scheme for the State of Tamil Nadu is given in Appendix I and II.

The Comprehensive Scheme contains data on inputs and output, relating to all crops grown on the selected holdings. Each crop is identified by its seed varieties. The analysis in this study is based on those plots growing exclusively HYV rice. The data set contains information pertaining to each plot within a farm as well as the entire farm and includes both quantitative and qualitative data[9].

Each crop has been classified according to the season of cultivation. Basically, four seasons have been taken into consideration: Kharif, Winter, Rabi and Summer. The analysis in the present study has been carried out for the two main rice growing seasons in the State, i.e., kharif: the first season which is sown in June-July and harvested in October-November, and rabi: the second season, sown in October-November and harvested in March-April.

The present analysis is, however, subject to certain limitations inherent in the data source used. The data set lacks plot-wise and crop-wise information on certain crucial variables, such as, capital expenditure, depreciation charges, interest rate, area under irrigation and rainfall. The methodological exercise had thus to be carried out by using proxies in place of the above

---

9 *The details of the plot-wise and farm-wise data on the different crops are given in Appendix III.*

mentioned variables. Chapter III on the estimation procedure details the list of the variables selected.

1.4 Chapter Outline

The present study is organised as follows:

Chapter II provides the analytical framework and methodology of the study. Chapter III deals with the procedure adopted for the estimation of technical efficiency and presents the results. Chapter IV examines the factors accounting for inter-farm differences in technical efficiency. The last chapter provides the main findings and conclusions of the study.

CHAPTER TWO

"At the core of Economics is the concept of efficiency."

(Leibenstein, 1966)

TECHNICAL EFFICIENCY: CONCEPT AND MEASUREMENT

This chapter attempts to review the recent literature on efficiency of resource-use in the production process. The review is undertaken at two levels: namely theoretical and empirical. At the theoretical level, the conceptualisation of efficiency and the different approaches to the measurement of technical efficiency is briefly dealt with. At the empirical level, recent studies on technical efficiency in agricultural production, using production frontier models, are reviewed to understand the problems involved in the measurement of variables and the estimation of production frontiers.

The organisation of this chapter is along the following lines. Section I deals with the concept of efficiency. Section II examines the different approaches to the measurement of technical efficiency including a detailed explanation of the model used in the present study. In Section III, a review of the recent empirical studies that have employed the production frontier methodology in the measurement of technical efficiency is provided. The fourth section provides the analytical framework for the present study.

2.1 Economic Efficiency: Concept and Its Dimensions

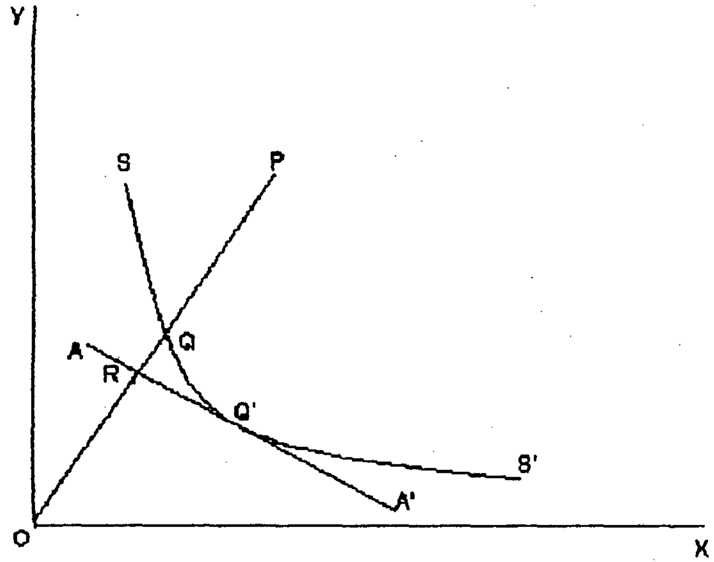
Speaking specifically in the context of agricultural production, economic efficiency refers to the ability of a farmer to allocate his resources to the production of different agricultural commodities in such a way that he gets maximum returns against the minimum sacrifice. Economic efficiency comprises of both technical efficiency and allocative efficiency. Technical efficiency is defined as the capacity and willingness of an economic unit (in this case a farmer) to produce the maximum possible output from a given bundle of inputs and technology. It deals with the management of the technology. Allocative efficiency, on the otherhand, refers to the ability and willingness of an economic unit to equate its specific marginal value product with its marginal cost. It is concerned with the achievement of maximum profits from varying factor proportions. Thus while technical inefficiency arises from excessive input usage, allocative inefficiency results from employing inputs in the wrong proportions. These different dimensions of efficiency may be more clearly understood from the following illustration[1].

Consider a farm employing two factors of production to produce a single output, under conditions of constant returns to scale. Suppose that the efficient production function is known, that is, the output that a perfectly efficient farmer could obtain from any given combination of inputs is given along with the respective price ratios, then, technical and allocative inefficiency may be defined relative to the production function of the efficient farmer. The assumption of constant returns permits all the information to be represented in a simple isoquant diagram (Fig. 2.1.1).

---

1 *Farrell, 1957.*

Figure 2.1.1
DIMENSIONS OF EFFICIENCY



In Figure 2.1.1, the isoquant **SS´** represents the combination of the two factors that a perfectly efficient farm might use to produce unit output. This isoquant sets the upper limit to the production technology. Given the technology and input prices, efficient operation in the sense of cost minimisation occurs at the point **Q´** on the isoquant, a point where the slope of the isocost line (**AA´**) is equal to the slope of the tangent of the isoquant. A farm that produces on the cost minimising point is said to be overall efficient/economically efficient. In the case of a farm that is not overall efficient, as represented by point **P**, the degree of overall efficiency is defined by the ratio **OR/OP**. The ratio **OR/OP** shows the fraction by which costs can be reduced if the farm **P** were to operate efficiently both in the technical and allocative sense. The distinction between technical and allocative efficiency may be made clear.

Point **Q**, in the figure represents a technically efficient farm using the two factors in the same ratio as **P**, but at the same time using only a fraction **OQ/OP** as much of each factor. This ratio **OQ/OP** is taken as the measure of `technical efficiency´ of the farm **P** and it takes the value of unity for a perfectly efficient farm and becomes indefinitely small as the amounts of input per unit of output become indefinitely large.

In order to measure the extent to which a farm uses the various factors of production in the best proportions, in view of their prices, which in the current terminology is referred to as allocative efficiency, the price line **AA´** is fitted in, with its slope equal to the ratio of the prices of the two factors. In this case the optimal method of production is represented by point **Q′** where the cost of production will only be a fraction **OR/OQ** of those at point **Q**. This ratio, **OR/OQ** is defined as the price efficiency/ allocative efficiency of point **Q** as well as **P**[2].

Overall efficiency or economic efficiency, it may be noticed, implies a farm to be both technically and allocatively efficient. In otherwords it is equal to the product of technical and allocative efficiencies, i.e.,

$$OQ/OP * OR/OQ = OR/OP$$

Of the above two mentioned components of economic efficiency, i.e., technical and allocative efficiency[3], it ought to be pointed out that the measurement of technical efficiency assumes greater importance given the high probability that where technical inefficiency exists, it is likely to exert an influence on allocative efficiency, thereby resulting in a cumulative negative effect on overall efficiency [4].

---

2 *It may be noted that any point that lies on the isoquant, **SS′**, represents a technically efficient farm. However, for a farm to be allocatively/price efficient the slope of its isocost line (**AA′**) should be equal to the slope of the isoquant (**SS′**).*

3 *For more detailed and indepth conceptualisations of efficiency see Hall (1959), Forsund and Hjalmarsson (1974) and Leibenstein (1966).*

4 *Kalirajan and Shand, 1994. In an earlier study, Liebenstein (1966) had shown that the gains accruing from technical efficiency were comparatively larger than the gains accruing from allocative efficiency. Here, it may be pointed out that Leibenstein spoke in terms of X-efficiency which as a concept is similar to technical efficiency (Maddala and Fishe, 1994).*

2.2 Approaches to Measurement of Technical Efficiency:

Several measures of efficiency[5] have been introduced in economic literature ranging from simple ratios to econometric modelling. For a long time, the average productivity of labour was considered adequate as a measure of efficiency. The criticism that this partial productivity measure ignores the effect of other inputs on efficiency led to the alternative measure of efficiency based on all inputs, that is, the total factor productivity (TFP) index. As the TFP index is constructed using weights, the measure suffers from the usual index number problem of fixing arbitrarily weights to different inputs (Farrell, 1957). Another measure of a farm's efficiency is its costs. However, measures based on costs reflect only the overall efficiency of a farm; failing to separate price/allocative and technical efficiency.

The above mentioned formulations of efficiency are termed as the classical approach, the constraints of which led to the development of the frontier based measurements of efficiency. Theoretically, the concept of a production frontier is none other than the production function which defines the maximum possible output for any given set of inputs. Any deviation from the frontier, thus, indicates the extent of a farm's inability to produce maximum output from its given set of inputs. The existence of such a gap between the potential and actual level of production forms the underlying principle for the measurement of technical efficiency under the production frontier approach wherein the degree of

---

5 *'Efficiency' shall henceforth refer to the concept of technical efficiency.*

technical efficiency is captured by an index measuring the ratio between actual and potential output.

More specifically, the production function of an inefficient farm, that does not produce the maximum possible output with the given inputs due to some slackness in production, say *i*, may be represented as:

$$\mathbf{Y_i = f(x_{i1}, x_{i2}, \ldots x_{im}) \exp(u_i)} \qquad (2.2.1)$$

where Y_i and x_i's are the output and inputs of the *ith* farm and u_i represents the combined effects of various non-price and socioeconomic factors which constrain the farmer from realising the maximum possible output. When a farm operates at its potential level, as represented by the frontier, u takes the value zero, implying that there are no socioeconomic constraints affecting the farm. When the farm faces constraints, u takes a value less than zero. In this case, a measure of the technical efficiency of the *ith* farm can be defined as:

$$\mathbf{\exp(u_i) = \frac{Y_i}{Y_i^*} = \frac{\text{Actual output}}{\text{Maximum possible output}}} \qquad (2.2.2)$$

The maximum possible output/production frontier, not being observable, must be estimated. Under the production frontier methodology, initiated by Farrell (1957), an efficient production function is estimated from observations of the inputs and outputs of a number of farms. Thus under this approach, technical efficiency is defined in relation to a given set of farms, in respect to a given set of factors measured in a specific way. A distinction may be made here between the conventional method of estimating the production function and the estimation of the production function under the frontier approach. The conventional production function assumes that all farms are efficient and hence operate on the frontier. This can be statistically estimated using the OLS regression technique and hence are average functions. The average functions are naturally associated with mean output, for given input levels as different from the frontier functions which are associated with maximal possible output.

There are two competing paradigms on how to estimate production frontiers under the production frontier methodology. One uses mathematical programming techniques (deterministic) while the other employs statistical methods (stochastic)[6]. A brief review of the various models under the two heads is made here to choose the approach for the present study.

2.3 The Production Frontier Models:

The Deterministic Production Frontier:

The deterministic frontier production function envisages a deterministic optimal relationship between inputs and output in the sense that all variations in farm performance is attributed to variations in farm efficiency alone. The deterministic approach consists of parametric and non-parametric techniques.

---

6 *A review of the various approaches under the deterministic and stochastic heads is provided in Forsund et al (1980), Kalirajan & Shand (1994) and Greene (1993). Bauer (1990) discusses the developments in the econometric approach to the estimation of stochastic frontiers.*

Deterministic Non-Parametric Frontiers:

Under the deterministic non-parametric programming technique, developed by Farrell (1957), the frontier is constructed as a free disposal convex hull of the observed input-output ratios by linear programming techniques. In otherwords the method consists of linear segments connecting the best technically efficient economic units against which the actual output of each sample observation is measured. The frontier is, thus, supported by a subset of the sample, with the rest of the sample points lying above it[7]. The approach is non-parametric in the sense that it is not based on any explicit model of the frontier[8]. The advantage of this approach is that no functional form needs to be imposed on the data. However, the approach suffers from the disadvantage that the frontier is computed from a supporting subset of observations from the sample, and is therefore particularly susceptible to extreme observations and measurement error (Forsund et al, 1980).

Deterministic Parametric Frontiers:

The deterministic parametric approach, proposed by Farrell (1957), is based on a parametric convex hull of the observed input-output ratios. He suggested that a functional form of the Cobb-Douglas type should be selected to determine the production function under the assumption of constant returns to scale (Farrell, 1957). Following Farrell's suggestion, Aigner and Chu (1968) specified a homogeneous Cobb-Douglas production frontier

---

7 *Here, it may be noted that Farrell (1957) expressed the frontier in terms of a cost function.*

8 *Forsund et al, 1980.*

with all observations required to lie on or beneath the frontier. Their model may be written as:

$$\ln y = \ln f(x) - u$$

$$= \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln x_i - u, \qquad u \geq 0 \qquad (2.3.1)$$

The one-sided error term in equation 2.3.1 forces $y \leq f(x)$. The elements of the parameter vector $\alpha=(\alpha_0, \alpha_1, \ldots, \alpha_n)'$ in equation 2.3.1 are, then, estimated by using either the linear programming or quadratic programming technique[8]. The technical efficiency of each observation is computed directly from the vector of residuals.

The difference between parametric and non- parametric programming is that the parametric frontier is smooth, while its non-parametric counterpart is piecewise linear. However, as is the case with the non-parametric approach, the 'estimated' frontier is supported by a subset of the data and is therefore extremely sensitive to outliers. One possibility suggested by Aigner and Chu (1968) and incorporated by Timmer (1971), is to discard a few observations. Timmer, thus, estimated the frontier, taking care of errors that are likely to arise in the data, in a probabilistic fashion by constraining *X* per cent of the observations to fall outside the frontier surface. The selection of this proportion is, however, essentially arbitrary, lacking explicit economic or statistical

---

8 *Under the linear programming technique, the sum of the* ***absolute*** *values of the residuals is minimised, subject to the constraint that each residual be non-positive, while under the quadratic programming technique, the sum of* ***squared*** *residuals is minimised, subject to the same constraint (Forsund et al, 1980).*

justification (Aigner et al, 1977). Moreover, the estimates obtained under this approach have no statistical properties as no assumptions are made about the regressors or the disturbance. However, the ability to characterize the frontier technology in a simple mathematical form and the ability to accommodate non-constant returns to scale makes it a better choice over the non-parametric approach (Forsund et al, 1980).

Deterministic Statistical Frontiers:

The deterministic models are made amenable to statistical analysis by making assumptions concerning the distribution of the error term that captures the extent of (in)efficiency. This was first explicitly proposed by Afriat (1972). He proposed a two-parameter gamma distribution for the error term and proposed that the model be estimated by the maximum likelihood method[10]. As with the other models under the deterministic approach, this method suffers from the drawback that it does not take into consideration the influence of random events and statistical noise such as measurement errors in estimating the technical efficiency of farms. This drawback in the deterministic models is overcome in the stochastic production frontier model, developed by Aigner et al (1977) and Meusen and Van den Broeck (1977).

Stochastic Frontier Models:

In the stochastic frontier models, inefficiency is modelled by a `composed´ error term, consisting of statistical noise and a one-

---

10 *Schmidt (1976) showed that Aigner and Chu´s linear programming procedure is maximum likelihood if `u´ is exponential, while their quadratic programming procedure is maximum likelihood if `u´ is half-normal.*

sided disturbance to allow for inefficiency. This method, thus, has an advantage over the mathematical (or programming) method as it allows for statistical noise resulting from the occurrence of events outside the farm's control such as pests and weather. The mathematical programming approach, on the otherhand, has the advantage that no explicit functional form needs to be imposed on the data. However, in this case the results can get distorted if the data is contaminated with statistical noise[11]. The foregoing review suggests that the stochastic production frontier methodology may be considered as the most appropriate model for analysing technical efficiency in agricultural production in Tamil Nadu as it can disentangle the effects of differences in agro-climatic zones on the estimation of technical efficiency[12].

2.4 Review of Empirical Studies:

An attempt is made to review briefly the recent studies on technical efficiency in agricultural production in developing countries in general and in India in particular. It may be noted at the outset that the review is limited to the studies which have used the production frontier framework.

In Kalirajan & Flinn (1983), technical efficiency is estimated using a stochastic translog production frontier for a sample of

---

11 *In a comparison of technical efficiency measures, obtained by employing the different models under the frontier approach, for a sample of 153 central Illinois grain farmers, Neff et al (1993), showed that the stochastic method results in much higher efficiency measures than the deterministic method, with approximately one-half of the farm efficiencies found by the deterministic method being attributed to random occurrences by the stochastic method.*

12 *A more disaggregated analysis at the zonal level is made difficult as certain zones contain too few observations (see Table 3.3.1 in Chapter III).*

rainfed rice farmers in Bicol, Philipines. The estimates obtained are farm-specific. The analysis reveals wide variation in the level of technical efficiency across sample farms, ranging from 0.38 to 0.91 with an average value of 0.50. Less than 20 per cent of the sample participants obtained output that is about 20 per cent below the maximum output estimated through the frontier. The study also examined the farm-specific factors (both biological and socio economic in nature) to provide an explanation for the variation in the levels of farm-specific technical efficiency. The method of crop establishment, extension officials contact and fertilizer application were identified as important factors causing variations in the level of technical efficiency among sample farmers.

Huang and Bagi (1984) estimated an index of technical inefficiency for individual farms in northwest India for 151 wheat farms in Punjab and Haryana during the agricultural year 1969-70 using the stochastic production frontier methodology. The average level of technical efficiency is estimated to be at 10.56 per cent. An examination of the levels of efficiency across the different size holdings revealed that there exists no significant difference in the technical efficiency of the small and large wheat farms.

The levels of technical efficiency in Basmati rice production in Gujranwala district of Pakistan are estimated by Flinn and Ali (1986) using a frontier production function. The modal level of technical inefficiency at farm-specific resource levels among 115 Basmati rice producers is found to be 20%. In terms of yield loss, it is estimated to be 0.4 tons per hectare. The better educated households are found to be more technically efficient. Late transplanting, late fertilizer application and water shortages are shown to have contributed significantly to farm-specific technical inefficiency.

Battese et al (1989) measured the level of technical efficiency in paddy production for a sample of 38 farmers from Aurepalle village in Andhra Pradesh, during the period 1975-76 to 1984-85, using the stochastic production frontier model. The predicted efficiencies ranged from 66 per cent to 91 per cent. The estimate of the mean efficiency of farmers was 83 per cent. About 23.7 per cent of the sample farmers were found to have predicted efficiencies of less than 8 per cent, whereas 52.6 per cent of the farmers had predicted efficiencies greater than 85 per cent.

Using an estimated probabilistic frontier production function, Ali & Chaudhry (1990) measure farm efficiency in four irrigated cropping regions of the Pakistan' Punjab for the year 1984-85. The findings show that the gross income of the farmers can be increased by 13% at the current levels of resource use if the production gap between the 'best practising farmers' and 'average farmers' is suitably narrowed in all cropping regions. Moreover, no significant difference in technical efficiency was found across the regions. Economic efficiency was observed to be similar across all cropping regions except in the cotton region, which had significantly lower economic efficiency due to higher allocative inefficiency.

The technical efficiency among rice cultivators in the rainfed lowlands of Antique province in the Phillipines during the first crop season of 1984-85 is estimated in Kalirajan and Shand (1994), using the stochastic production frontier methodology. The analysis is carried out separately for three municipalities, Dao, Pandan and Patnongon, in Antique province. The estimates revealed wide variation in efficiency both within and across the municipalities. The mean efficiency was found to be the highest among the Pandan sample farmers (77%). The Dao and Pantnongon sample farmers, on the otherhand, showed a mean efficiency of around 49 per cent and 42 per cent respectively. On the average, it was observed that non-owner farmers performed better than the owners in the Pandan and Patnongon municipalities.

Kalirajan and Shand (1994) estimated technical efficiency in agricultural production for a sample of sixty farmers in Ramnad district of Tamil Nadu during the period 1980-81. The empirical results showed only about 65 per cent mean technical efficiency for the rice crop, 72 per cent for the corn crop and 68 per cent for the second rice crop, implying that the corn production technology, on average, has been used more efficiently by the sample participants. The results showed the levels of crop-specific and farm-specific efficiency to vary widely among the sample farmers. Among the factors identified for explaining the wide variation of farm-specific technical efficiency, farming experience and extension officials visits were found to be important factors in the case of rice, while corn production was shown to be highly dependent on financial availability.

The above review suggests that the stochastic production frontier framework is increasingly being used to examine the extent of farm-specific technical (in)efficiency in agricultural production.

2.5 Stochastic Production Frontier Framework

This section provides an analytical framework for analysing farm-specific technical efficiency in rice production in Tamil Nadu. The stochastic production frontier framework developed by Aigner, Lovell and Schmidt (1977) is presented here. Taking the example of a location with n farms producing a homogeneous output y and using a set of inputs x_i's, the production possibilities can be described as:

$$y_i = f_i(x_1, x_2, \ldots, x_m), \; i = 1, 2, \ldots, n. \qquad (2.5.1)$$

The best practice or frontier production function is then defined as:

$$y^* = \max_i f_i(x_1, x_2, \ldots, x_m)/T \qquad (2.5.2)$$

where T refers to the level of technology known to the farms in the location, the understanding and use of which varies from farm to farm at any point of time. The frontier function thus refers to those farms' production functions that yield maximum output from given quantities of a set of inputs. Consequently, any observed levels of production should lie either on or below the frontier production function. Therefore the basic model of maximum production can be written as:

$$y = f(x) + u \qquad (2.5.3)$$

where y refers to actual output, $f(x)$ is the transformation between inputs x and output y, and u is a technical efficiency parameter. The parameter u takes the value of zero or less than zero depending on whether the observation y lies on or below the frontier.

The above equation is deterministic and here the value of u will vary among farms depending on their `technical efficiency'. However, the maximum output y may vary randomly across farms or over time for the same farm due to factors other than efficiency. To allow for this reality, a random variable v is added to the equation. It then becomes a stochastic production frontier model in which the error term is decomposed as follows:

$$y = f(x) + u + v \qquad (2.5.4)$$

The presence of v in equation (2.5.4) means that y is stochastic and that v captures other random factors, such as, errors in measurements, weather, etc. The value of v in the equation may be either positive, negative or zero and it is assumed to follow a normal distribution (that is, $v \sim N(\emptyset, \sigma^2)$). Once the functional form and the distribution of the `farm-specific error term' are specified the stochastic frontier production function is then estimated empirically, making use of maximum likelihood techniques.

Distributional Assumptions of the One-Sided Error Term:

Four distributions of the one sided error term have been assumed in the literature: half normal, truncated normal, exponential and gamma. There is however no objective *a priori* basis for choosing one distribution over another. In practice this choice is usually made for reasons of convenience and the most popular choice in the literature has been the half-normal distribution (Forsund et al, 1980; Battese et al, 1989; James, 1996a).

Once the distribution of the components of the error term has been specified, the maximum possible output function is obtained through the maximum likelihood method of estimation. This requires that density functions for random variables u and v are given. Under the assumption that u follows a half-normal distribution (as in the present study) and v follows a conventional normal distribution, the density functions of u and v can respectively be written as:[13]

$$f_u(u) = \frac{1}{\sqrt{½\pi}} * \frac{1}{\sigma_u} \exp(-u^2/2\sigma^2{}_u) \qquad u \leq 0 \qquad (2.5.5)$$

$$f_v(v) = \frac{1}{\sqrt{2\pi}} * \frac{1}{\sigma_v} \exp(v^2/2\sigma^2{}_v) \qquad -\infty \leq v \leq \infty \qquad (2.5.6)$$

where, $\sigma^2 u$ and $\sigma^2 v$ are the variances of the one-sided error term and the random efficiency component respectively. The density function of y (eq. 2.57) which is the joint density function of $(u + v)$ is given as:

---

[13] *Kalirajan and Shand, 1994.*

$$f(y) = \frac{1}{\sigma\sqrt{\pi/2}} \exp\left(\frac{(u + v)^2}{2\sigma^2} \right) [1-F[(u+v/\sigma)(\tau/1-\tau)]] \quad (2.5.7)$$

where;

(i) F(.) is the cumulative distribution of the standard normal random variable,

(ii) $\sigma^2 = \sigma^2_u + \sigma^2_v$,

(iii) $\tau = \sigma^2_u/\sigma^2$ where τ lies in the interval (Ø,1), and

The likelihood function corresponding to (2.5.7) is given as:

$$L(y,\theta)= \pi \left[\frac{1}{\sigma\sqrt{\pi/2}} \exp\left(- \frac{(u+v)^2}{2\sigma^2}\right)\right][(1-F[(\frac{u+v}{\sigma})(\frac{\tau}{1-\tau})]] \quad (2.5.8)$$

where θ is the parameter to be estimated which includes the production parameters, the elements of σ^2 and τ.

The maximum likelihood (ML) estimators of θ maximising the above likelihood function are obtained by setting its first order partial derivatives with respect to the elements of θ equal to zero, and solving them simultaneously[14].

The Estimation of Farm-Specific Technical Efficiency:

From the model introduced by Aigner, Lovell and Schmidt (1977) and Meusen and van den Broeck (1977) the average technical efficiency, given by the mean of the distribution of u_i can be easily calculated from the variance of the one-sided error component. In the half-normal case this would be $-\sigma_u\sqrt{(2/\pi)}$. The average technical efficiency can also be estimated by the average of $\hat{\epsilon}_i$. However, a measure of efficiency based on the average does not enable a

---

[14] *Kalirajan and Flinn, 1983.*

comparison of the efficiency levels across observations which had been Farrell's original idea in introducing production frontiers.

Jondrow, Lovell, Materov and Schmidt (1982) suggests a solution to the problem by separating the error term (ϵ), in the stochastic frontier model, into its two components, v and u, by considering the expected value of u, conditional on $(v-u)$. Their formula for the half-normal case is given as:

$$E(u \backslash \epsilon)=\mu^{*}+\sigma^{*} \frac{f(-\mu^{*}/\sigma^{*})}{1-F(-\mu^{*}/\sigma^{*})} \qquad (2.5.9)$$

where f and F represent the standard normal density and distribution functions, respectively and;

$\epsilon=(v-u)$

$\mu^{*}=-\sigma^{2}{}_{u}\epsilon/\sigma^{2}$,

$\sigma^{*2}=\sigma^{2}{}_{u}\sigma^{2}{}_{v}/\sigma^{2}$,

$\sigma^{2}=\sigma^{2}{}_{u}+\sigma^{2}{}_{v}$.

$\sigma^{2}{}_{u}$: is the variance of the one-sided error term, and

$\sigma^{2}{}_{v}$: is the variance of the random error term.

The present study employs the above model in estimating the farm-specific levels of technical efficiency among rice cultivators in Tamil Nadu.

CHAPTER THREE

"Efficiency scores are performance indicators, like won-lost percentages, and so they are of considerable interest in their own right."

(Lovell, C. A. K, 1993)

TECHNICAL EFFICIENCY IN RICE CULTIVATION IN TAMIL NADU (1992 -93).

This chapter examines farm-specific technical (in)efficiency in rice production in Tamil Nadu for the year 1992-93 within the Stochastic Production Frontier framework as outlined in Chapter II. The analysis has been carried out, separately, for the two main agricultural seasons of kharif and rabi to examine the seasonal difference in the level of technical (in)efficiency. An attempt is also made to find out the relationships between agro-climatic zones and the level of technical efficiency.

The chapter is divided into four sections. Section I specifies the stochastic production frontier for both seasons separately, discusses the measurement of variables selected and highlights some of the distributional characteristics of variables under study. Section II reports the empirical results separately for kharif and rabi seasons. Section III looks into the variation in technical efficiency across agro-climatic zones. The final section summarises the major findings.

3.1 Specification of Production Frontier for Rice Farms

The first step in any production function analysis lies in the specification of the functional form that posits a given relationship between the inputs and output (Rudra, 1967; Fuss and McFadden, 1978; Varagunasingh, 1993). The stochastic production frontier for the rice production process in Tamil Nadu is assumed to take the following non-homothetic (translog) functional form:

$$\log Y = \alpha_o + \Sigma \beta_i \log X_i + \Sigma\Sigma \beta_{ij} (\log X_i)(\log X_j) + u_i^- + v_i \qquad (3.1.1)$$

where Y represents the output, the X_is stand for the respective inputs, u_i is the technical efficiency component of the error term (ϵ) and v_i is its random component.

A statistical test is carried out to test whether the functional form of the production frontier is non-homothetic (Translog) or homothetic (Cobb-Douglas). The non-homothetic production frontier becomes Cobb-Douglas, when all the interaction terms (β_{ij}'s) in equation 3.1.1 are zero. The conventional F-test is carried out to test the null hypothesis that all $\beta_{ij} = 0$ (Gujarati, 1995). The computed F values, for both seasons, turn out to be lesser than the tabulated value of F at the one per cent level of significance (see Appendix IV for details). The null hypothesis that all $\beta_{ij} = 0$ is, therefore, accepted. Hence, the Cobb-Douglas (homothetic) functional form fits the data better than the translog (non-homothetic) functional form. It is therefore decided to use the Cobb-Douglas production frontier for the present study. The specification of the Cobb-Douglas production frontier is as follows.

$$\mathrm{Log}Y_i = \alpha_0 + \Sigma\beta_i \log X_i + u_i + v_i \qquad (3.1.2)$$

Specification of Variables

The variables that represent the factors of production and the output are as important as the specification of the functional form. The variables specified, in fact, should conform to the underlying theoretical constructs. Any deviation from the theoretical constructs is often termed as measurement errors in variables. Thus, the problems of measurement in variables becomes an important issue in the applied econometric work (Rudra, 1967; Heady and Dillon, 1969; Varadarajan, 1993).

An attempt is made to discuss briefly the measurement of variables under study. In the above equation (3.1.2) Y is the output and X_i refers to different inputs. The chosen production frontier assumes five inputs namely area, labour, farm power, materials and seeds which are discussed in detail:

Output: is HYV paddy, that is the main product, in quintals.

Area: is the net sown area(in hectares) cultivated with HYV rice.

Labour: is the total number of labour hours employed of family, servant and casual labour in paddy production.

Farm Power: is the sum of the hours employed of tractor power and animal power; combined together by converting them to their value equivalents (Ali & Chaudry, 1990). This variable has been taken as a proxy for capital services. The underlying rationale[1] is that the two can be substitutes to each other as revealed by the fact that farms which do not use tractors for cultivation have longer hours of animal power employed. Moreover, the farm power is often mixed at varying proportions between hired and owned. In some cases, the farm uses either hired power or owned power. This is true for both tractor as well as animal power.

---

1 *Heady and Dillon, 1969.*

As information relating to the market price of employing tractor or animal power is provided only for the hired category, the market value of the owned machinery (tractor) or animal power in farm use needs to be imputed for each zone. This was done in two stages: (i) the average per hour hire charge in the case of hired category of tractors and animal power is computed under the assumption that the hire charge does not vary much within the zones; and (ii) the market value of owned tractors and animals in farm use are imputed by multiplying the hours of owned tractors and animals with the zone-wise average per hour hire charge.

Materials: is the total value of fertilizers (composed of Nitrogen, Potassium and Phosphorus), pesticides and organic manure applied, and

Seed: is the HYV seed measured in physical units, that is, kilograms.

These variables under study are generated at farm level for the sample size. The sample size for the seasons of kharif and rabi are different. The sample size for kharif season is 146 farms whereas the sample size for rabi season is 179 farms. In few cases, the farm units are found to be same for both the seasons. An examination of the distributional characteristics of the selected variables would throw some light on the nature of the samples under study.

The descriptive statistics for each of the variables under study for both the seasons are computed (Table 3.1.1). They include mean, standard deviation, co-efficient of variation, minimum and maximum values. The minimum and maximum values reveal the absolute range within which each variable assumes its distribution. The co-efficient of variation computed for each variable, in fact, enables us to compare the variability between the distributions of the variables. The use of power (mechanical and animal) and seeds is seen to vary more widely among the farms for both the seasons. Inter-farm differences in all variables under study are quite high regardless of the seasons. But, it may be noted that the mean level of variables for the kharif season is relatively higher than that for the rabi season which may be an indication of relatively higher levels of efficiency in input usage in the rabi season.

Table 3.1.1

DISTRIBUTIONAL CHARACTERISTICS OF SELECTED VARIABLES

Kharif Season		**Sample Size = 146 farms**			
Variable (for holding)	**Mean**	**Standard Deviation**	**Co-efficient of Variation (%)**	**Minimum**	**Maximum**
Area (hectares)	1.3174	1.4585	111	0.06	7.470
Labour (hours)	1734.4	1638.4	94	167	9771
Farm Power (Rs.)	1245.9	1707.6	137	39.12	11010
Materials (Rs.)	2307.1	2625.1	114	92.50	13610
Seed (kgs.)	114.07	151.55	133	5	1360
Output (quintals)	61.994	70.971	114	2.25	438.6
Rabi Season		**No. of Observations = 179**			
Variable (for holding)	**Mean**	**Standard Deviation**	**Co-efficient of Variation (%)**	**Minimum**	**Maximum**
Area (hectare)	1.16	1.227	106	0.05	7.87
Labour (hours)	1622.2	1535.3	95	88.58	10320
Farm Power (Rs.)	1083.7	1220	113	18.34	7835
Materials (Rs.)	2237.6	2625.3	117	24.50	18190
Seed (kgs.)	109.04	152.15	140	1.2	1602
Output (quintal)	53.75	61.099	114	0.82	372

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).

Testing for Multicollinearity:

The high degree of collinearity (above Ø.7) between the explanatory variables (Table 3.1.2) makes it necessary to test for the extent of multicollinearity among the independent variables in the production frontier model.

Table 3.1.2

CORRELATION MATRIX

Kharif Season					
Variables	**Area**	**Labour**	**Power**	**Mater**	**Seed**
Area	1				
Labour	Ø.93423	1			
Farm Power	Ø.76999	Ø.76466	1		
Materials	Ø.87Ø9Ø	Ø.88637	Ø.81286	1	
Seed	Ø.8Ø757	Ø.7Ø477	Ø.5885Ø	Ø.68959	1
Rabi Season					
Variables	**Area**	**Labour**	**Power**	**Mater**	**Seed**
Area	1				
Labour	Ø.91597	1			
Farm Power	Ø.84736	Ø.84153	1		
Materials	Ø.89773	Ø.85358	Ø.8188Ø	1	
Seed	Ø.66775	Ø.623Ø2	Ø.54Ø82	Ø.58846	1

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).

As to whether multicollinearity can pose a problem, if present, can be determined by obtaining the condition number (CN) of the data matrix of the explanatory variables. This basically involves determining the square root of the ratio of the highest to the lowest characteristic roots of the matrix formed by premultiplying the data matrix (X) by its transpose (X′), ie., the moment matrix. Symbolically:

$$CN = (\lambda_{max}/\lambda_{min})^{1/2}$$

where CN is the condition number and λ min and λ max are the smallest and the largest characteristic roots of the moment matrix.

The CN is computed for both the seasons. It is found that the CN is 12.63 for kharif season and 10.95 for rabi season. Quoting Belsley (1991, pp.56) that "weak dependencies are associated with condition indexes around 5 - 10, whereas moderate to strong relations are associated with condition indexes of 30 - 100", it may be safely stated that the problem of multicollinearity may not pose a problem for the present analysis.

3.2 Empirical Results

The production frontier model for rice crop under kharif and rabi seasons are estimated separately. As pointed out in the earlier section, the sample size of the study varies between the seasons.

As a prelude, it is important to keep in mind that Tamil Nadu receives more rains during the north-east monsoon (October-December), which is the summer season (rabi) for all other states in India[2]. This gives rise to some terminological problems of

---

[2] *Table 3.2.1*
Classification of Major Seasons During the Rainfall Year 1992-93.

State	South-west (Kharif)	North-east (Rabi)	Winter	Summer
Tamil Nadu	June-September	October-December	January-February	March-May

Source: Season and Crop Report of Tamil Nadu (1992-93).

dividing the agricultural year by seasons. As is well known most parts of India receive rain during the south-west monsoon. However, Tamil Nadu receives scanty rain during this period except for the Cauvery basin where farmers benefit from the south-west monsoon in Karnataka through canal irrigation and Kanyakumari district which receives both south-west and north-east monsoons. Given this regional specificity in the occurrence of monsoon in Tamil Nadu, it is better to call, hereafter, the rabi crop receiving the north-east monsoon as monsoon crop and the kharif crop as lean season crop. The rabi crop being the actual monsoon crop for Tamil Nadu is the dominant season for rice cultivation in the state. Therefore, the present study first examines the farm efficiency in monsoon crop and then moves onto the lean season crop.

Efficiency Results: Monsoon Crop

Technical (in)efficiency in rice production during the monsoon season has been estimated using Cobb-Douglas production frontier. To get a better understanding of the extent of technical (in)efficiency, both the conventional production function approach and the production frontier approach have been employed. The conventional production function is estimated through ordinary least squares (OLS), whereas the production frontier is estimated using maximum likelihood estimates. As pointed out in the second chapter, the conventional production function shows the response of the 'average farmer' in allocating the farm resources optimally while the production frontier reveals the response of 'best farmer' in allocating the farm resources optimally. A comparison between the OLS and MLE estimates is, thus, carried out in order to capture the extent of technical (in)efficiency within the sample farms.

The OLS results for the monsoon season are shown in Table 3.2.2. All the variables except seed are found to be significant at the one per cent level. The seed variable is significant at the ten per cent level. Here, it may be pointed out that seed as an input may not be an important explanatory variable as all the farms under study use the seed of High Yielding Variety. Among the other explanatory variables, acreage response seems to be a dominant variable followed by labour, materials and farm power. Mechanisation (tractor) and application of fertilizers and pesticides increases marginally the output whereas additional output would generate additional employment opportunities in rice cultivation.

Table 3.2.2
PRODUCTION ELASTICITIES FOR MONSOON SEASON

Variable	Co-efficient
Constant	0.044872 (0.086)
Area	0.52572 (7.404)*
Labour	0.26228 (4.026)*
Farm Power	0.10719 (3.262)*
Materials	0.11036 (3.398)*
Seed	0.064005 (1.708)**
No. of Observations: 179	$\bar{R}^2$ = 0.95

Source: *Cost of Cultivation Data for Tamil Nadu (1992-93).*

Note: *The figures in parenthesis are the respective t-ratios.*
** Significant at the one percent level.*
*** Significant at the ten percent level.*

As the average farmer's response is not the same as that of the best practice farmer, the stochastic production frontier is estimated using the maximum likelihood technique. The results of MLE are presented in Table 3.2.3. As far as the input elasticities are concerned, there is not much difference between the estimates of OLS and MLE. The intercept term in MLE is relatively higher than the OLS estimate, implying that the frontier farmers use relatively lesser inputs than the average farmers for obtaining a given level of output.

Table 3.2.3

MLE OF PRODUCTION FRONTIER MODEL FOR MONSOON SEASON

Variable	Co-efficient
Constant	0.154 (0.397)
Area	0.507 (10.048)*
Labour	0.286 (4.209)*
Farm Power	0.099 (2.654)*
Materials	0.112 (3.321)*
Seed	0.057 (1.493)
σ_u/σ_v	1.23
$\sigma^2_u/(\sigma^2_u + \sigma^2_v)$	0.601
Log-Likelihood	13.141

Source: *Cost of Cultivation Data for Tamil Nadu (1992-93).*

Note: *The figures in parenthesis are the respective t-ratios.*

** Significant at the one percent level.*

From the estimates of $\sigma^2u/(\sigma^2u + \sigma^2v)$ and $\sigma u/\sigma v$ in Table 3.2.3, it can be seen that the technical efficiency component of the error term dominates the source of random variation in the model (see Appendix V for details). The *population* average technical inefficiency is calculated from the variance of the *u* term, using the equation $-\sigma_u\sqrt{2/\pi}^{s}$, to be Ø.16; implying that the `average' farms produce output 16 per cent below the maximum output as determined by the frontier.

In order to judge one unit's performance relative to another when different factor amounts and proportions are employed, the individual specific technical efficiency (e^{-u_i}) has to be estimated. This has been calculated using equation 2.5.9 in Chapter 2. The estimates of farm-specific technical efficiency are provided in Appendix VI. The frequency distribution of farm-specific technical efficiency reveals that sixty eight per cent of the farmers produce output within the twenty per cent below the maximum output as represented by the frontier though the farm-specific technical efficiency varies between 45 and 97 per cent (see Table 3.2.4).

---

[s] *Kalirajan and Flinn, 1983.*

Table 3.2.4

FREQUENCY DISTRIBUTION OF TECHNICAL EFFICIENCY FOR MONSOON SEASON

Range	Frequency	Cumulative Frequency
Ø.45 - Ø.5Ø	1 (Ø.56)	1 (Ø.56)
Ø.5Ø - Ø.55	2 (1.12)	3 (1.68)
Ø.55 - Ø.6Ø	2 (1.12)	5 (2.79)
Ø.6Ø - Ø.65	6 (3.35)	11 (6.15)
Ø.65 - Ø.7Ø	6 (3.35)	17 (9.5)
Ø.7Ø - Ø.75	17 (9.5Ø)	34 (19.Ø)
Ø.75 - Ø.8Ø	23 (12.85)	57 (31.84)
Ø.8Ø - Ø.85	49 (27.37)	1Ø6 (59.22)
Ø.85 - Ø.9Ø	52 (29.Ø5)	158 (88.27)
Ø.9Ø - Ø.95	2Ø (11.17)	178 (99.44)
Ø.95 - 1.ØØ	1 (Ø.56)	179 (1ØØ)

Source: *Cost of Cultivation Data for Tamil Nadu (1992-93).*
Note: *Figures in parenthesis are percentages.*

A bivariate analysis of technical efficiency in rice cultivation by efficiency level and area under rice crop provides some insights into the relationship between technical efficiency and the size of the operated holding. As can be seen from Table 3.2.5, nearly two-thirds of the sample farms under the monsoon season are marginal holdings cultivating paddy in plots less than one hectare. Small holdings with area cultivated between one and two hectares account for about little more than one-fifth of the sample farms in the monsoon season while the rest of the sample is constituted by farms cultivating paddy in plots more than two hectares. This shows that the sample for the monsoon season represents more of the marginal and small holdings.

Table 3.2.5

DISTRIBUTION OF FARMS IN MONSOON SEASON BY TECHNICAL EFFICIENCY AND SIZE OF RICE PLOTS.

Area Under Rice Crop (hectares)	Technical Efficiency			
	< Ø.5Ø	Ø.5Ø - Ø.75	> Ø.75	Row Total
< 1	1	24	87	112 (62.6)
1 - 2		7	33	4Ø (22.3)
2 - 3		2	12	14 (7.8)
> 3			13	13 (7.3)
Column Total	1 (Ø.6)	33 (18.4)	145 (81)	179 (1ØØ)

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).
Note: Figures in parenthesis are the respective percentages.

The efficiency distribution of these farms reveals that the relatively inefficient farms are concentrated in the category of marginal holdings (see Table 3.2.5). It may be noted from the above table that during the monsoon season farms have relatively higher levels of technical efficiency as the size of the operated holding increases.

The Empirical Results: Lean Season Crop

The OLS estimates of the production elasticities are presented in Table 3.2.6. The input co-efficients of area and materials turn out significant at five per cent level. The co-efficient of labour, seed and farm power turn out to be insignificant. The insignificance of critical inputs suggests that the factors beyond the control of farmers could have adversely affected the realisation of maximum possible output. Kharif season being the lean season crop in Tamil Nadu might have possibly worsened the constraints on farms in applying timely the critical inputs. For example, the marginal and small holdings cultivating paddy as lean season crop might not have access to water, credit facilities, etc. This kind of unfavourable condition may perhaps sometimes result in crop failure as well. However, the medium and large holdings may not face such constraints in the cultivation of the lean season crop. Besides, the persistence of surplus labour/disguised unemployment in agriculture, particularly at the level of marginal holdings may also affect farm production during the lean season.

Table 3.2.6
OLS ESTIMATES: LEAN SEASON

Variable	Co-efficient
Constant	3.7598 (4.962)*
Area	0.99326 (9.130)*
Labour	-0.0939 (-1.091)
Farm Power	0.0031 (0.081)
Materials	0.1015 (1.984)**
Seed	-0.0076 (-0.099)
No. of Observations: 146	$\bar{R}^2$ = 0.94

Source: *Cost of Cultivation Data for Tamil Nadu (1992-93).*
Note: *Figures in parenthesis are the respective t-ratios.*
** Significant at one per cent level.*
*** Significant at five per cent level.*

Keeping these constraints in view, the exercise has been carried out for different size-classes of holding[4]. The total sample is divided into three sub-samples, namely (i) marginal holdings (below one hectare), (ii) marginal and small holdings (below two hectares), and (iii) marginal, small and semi-medium holdings (below three hectares). The seed as an input variable is dropped at the disaggregated analysis as all farms under study use only High-Yielding Varieties. Table 3.2.7 shows the input elasticities for the marginal holdings to be different from those of the small and medium holdings.

Table 3.2.7

OLS ESTIMATES FOR DIFFERENT SIZE-HOLDINGS: LEAN SEASON

Variable	Total Sample	< 3 Hectares	< 2 Hectares	< 1 Hectare
Constant	3.7295 (5.39)*	3.32 (4.29)*	3.22 (3.88)*	4.471 (4.46)*
Area	Ø.98642 (11.656)*	Ø.939 (9.66)*	Ø.92Ø7 (8.76)*	Ø.986 (8.18)*
Labour	-Ø.Ø9458 (-1.11)	-Ø.Ø58 (-Ø.6)	-Ø.Ø42 (-Ø.4)	-Ø.246 (-2.1)**
Farm Power	Ø.ØØ356 (Ø.Ø9)	-Ø.ØØ9 (-Ø.2)	-Ø.Ø11 (-Ø.3)	Ø.129 (2.17)**
Materials	Ø.1Ø128 (1.99)**	Ø.132 (2.37)**	Ø.131 (2.22)**	Ø.Ø26 (Ø.37)
No.of Cases	146	13Ø	121	82
$\bar{R}^2$	Ø.94	Ø.9	Ø.9	Ø.9

Source: *Cost of Cultivation Data for Tamil Nadu (1992-93).*
Note: ** Significant at one per cent level.*
*** Significant at five per cent level.*

---

4 *The size of a holding here is defined in relation to the area under the paddy crop.*

The estimates in Table 3.2.7 suggests that the relation between inputs and output are different for marginal holdings. For instance, the labour and farm power inputs are significant for the marginal holdings. The material input which is significant for the total sample of farms as well as small and medium farms, is insignificant for the marginal holdings. Regardless of the size of area under cultivation, the acreage response is observed to be significant. An interesting observation is that output elasticity of labour is negative and significant whereas the output elasticity of farm power is positive and significant for the marginal holdings. It implies that apart from the positive response of acreage and farm power, the withdrawal of surplus labour from farm activity would possibly improve the technical efficiency of marginal holdings. In case of small and large holdings, additional output would not require additional labour and additional farm power. Instead, it may necessitate additional fertilizers and organic manure. It may be inferred that a part of the explanation for technical inefficiency among the farms, particularly marginal holdings, lies in the presence of surplus labour in agriculture.

Coming to the maximum likelihood estimates of the production frontier for the lean season, it is seen from Table 3.2.8 that acreage response and fertilizer consumption (materials in use) are positive and significant while the labour co-efficient is significant and negative for all farms, except the marginal holdings, in the lean season. The farm power consisting of animal power and tractor power is not significant. This is true for the different size-classes of holdings as well. The materials input turns out insignificant for the marginal holdings. It is evident that the co-efficient of labour is getting weakened as the size of area under paddy cultivation increases, implying that maximisation of output is possible by withdrawing surplus labour from farm activity. The magnitude of the labour co-efficient indicates that the small holdings have relatively more disguised unemployment. This may be possibly due to the non-availability of non-farm employment opportunities during the lean season.

Table 3.2.8
MLE FOR DIFFERENT SIZE-HOLDINGS: LEAN SEASON

Variable	Total Sample	< 3 Hectares	< 2 Hectares	< 1 Hectare
Constant	4.7262 (6.56)*	4.69 (5.78)*	4.331 (4.91)*	5.15 (3.52)*
Area	1.0561 (12.18)*	1.06 (10.8)*	1.014 (8.97)*	1.076 (6.03)*
Labour	-0.2194 (-2.4)**	-0.21 (-2.1)**	-0.174 (-1.7)***	-0.262 (-1.62)
Farm Power	-0.0010 (-0.03)	-0.01 (-0.3)	-0.014 (-0.3)	0.0522 (0.804)
Materials	0.13328 (3.65)*	0.144 (3.48)*	0.154 (3.51)*	0.0612 (0.817)
No. of Observations	146	130	121	82
Log-Likelihood	18.07	13.3	11.7	6.8

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).
Note: Figures in parenthesis are the respective t-ratios.
** Significant at one per cent level.*
*** Significant at five per cent level.*
**** Significant at ten per cent level.*

The Efficiency Estimates For Entire Sample (Lean Season)

The efficiency results presented here pertain to the entire sample. The MLE estimates of the parameters of the frontier production function are reported Table 3.2.9.

Table 3.2.9

MLE ESTIMATES OF PRODUCTION FRONTIER: LEAN SEASON

Variable	Co-efficient
Constant	4.616 (5.464)*
Area	1.033 (8.064)*
Labour	-0.217 (-2.339)**
Farm Power	0.0009 (0.024)
Materials	0.132 (3.303)*
Seed	0.021 (0.201)
σ_u/σ_v	4.575
$\sigma^2_u/(\sigma^2_u + \sigma^2_v)$	0.9544
Log-Likelihood	18.105

Source: *Cost of Cultivation Data for Tamil Nadu (1992-93).*
Note: * *Significant at one per cent level.*
** *Significant at five per cent level.*
Figures in parenthesis are t-ratios.

The MLE estimates which reflects the response of the best practice farms are more or less similar with the OLS estimates (Table 3.2.6). The constant term of the MLE result is relatively higher than that of the OLS estimate. Thus, comparing production curves, the frontier envelope as obtained through maximum likelihood estimation, shifts upward with a shift in intercept of the production function. It implies that the frontier units use relatively lesser inputs than the average farms.

The variance ratio parameter[5], given by $\sigma^2_u/(\sigma^2_v + \sigma^2_u)$, takes the value Ø.95 which is comparatively large, given the interval within which it lies (i.e., between Ø and 1). This value implies that about 95 per cent of the difference between the observed output and the maximum production frontier output is caused by differences in farmers' levels of technical efficiency as opposed to the conventional random variability. The source of random variation can also be estimated from the ratio: σ_u/σ_v, which takes the value of 4.58, again implying that the technical efficiency component of the error term dominates the source of random variation in the model (see Appendix V for details)

From the variance of the technical efficiency parameter, i.e. σ^2_u, the population average technical efficiency is calculated to be Ø.23; implying that on the average there is 23 per cent technical inefficiency in the sample. In otherwords, the actual farm output of the 'average' farmer is 23 per cent less than the maximal output that can be attained with the existing level of inputs. In terms of technical efficiency, this would imply the farmers in the sample to have an average technical efficiency level of 77 per cent. Thus, on the average, there exists the scope of increasing production further through a 23 per cent improvement in the technical efficiency of the 'average' farmer. The frequency distribution of farms belonging to the lean season by technical efficiency shows that around 46 per cent of the farmers obtained output within 2Ø per cent below the maximum output estimated through the frontier (see Table 3.2.1Ø). The technical efficiency of individual farms varies from 3Ø to 97 per cent.

---

5 *Kalirajan and Flinn, 1983.*

Table 3.2.10
FREQUENCY DISTRIBUTION OF TECHNICAL EFFICIENCY
LEAN SEASON

Range	**Frequency**	**Cumulative Frequency**
0.30 - 0.35	3 (2.05)	3 (2.05)
0.35 - 0.40	2 (1.37)	5 (3.42)
0.40 - 0.45	0	5 (3.42)
0.45 - 0.50	2 (1.37)	7 (4.79)
0.50 - 0.55	4 (2.74)	11 (7.53)
0.55 - 0.60	9 (6.16)	20 (13.70)
0.60 - 0.65	15 (10.27)	35 (23.97)
0.65 - 0.70	17 (11.64)	52 (35.62)
0.70 - 0.75	11 (7.53)	63 (43.15)
0.75 - 0.80	16 (10.96)	79 (54.11)
0.80 - 0.85	17 (11.64)	96 (65.75)
0.85 - 0.90	20 (13.70)	116 (79.45)
0.90 - 0.95	21 (14.38)	137 (93.84)
0.95 - 1.00	9 (6.16)	146 (100)

Source: *Cost of Cultivation Data for Tamil Nadu (1992-93).*
Note: *Figures in parenthesis are percentages.*

The bivariate analysis of technical efficiency by size of rice plot holdings suggests that the inefficient farms are found to be concentrated in the size class of marginal and small holdings and the medium and large farms are relatively more efficient (see Table 3.2.11).

Table 3.2.11

TECHNICAL EFFICIENCY BY SIZE OF RICE PLOT HOLDING: LEAN SEASON

AREA (in hectares)	EFFICIENCY			
	< Ø.5Ø	Ø.5Ø - Ø.75	> Ø.75	Row Total
< 1	4	33	45	82 (56.2)
1 - 2	3	13	23	39 (26.7)
2 - 3		4	5	9 (6.2)
> 3		6	1Ø	16 (11.Ø)
Column Total	7 (4.8)	56 (38.4)	83 (56.8)	146 (1ØØ)

Source: *Cost of Cultivation Data for Tamil Nadu (1992-93).*
Note: *Figures in parenthesis are percentages.*

It is evident that out of 82 marginal holdings, 33 holdings fall in the efficiency range of Ø.5Ø to Ø.75 per cent, while four holdings have technical efficiency below Ø.5Ø per cent. This points out that the extent of technical inefficiency is relatively more among the marginal and small holdings where disguised unemployment is found to be widespread. It may be therefore argued that regardless of the seasons, increasing the area under the paddy crop through the consolidation of marginal holdings may have the potentiality of increasing actual output closer to the frontier output by enhancing technical efficiency which further calls for the removal of surplus labour from the operating units.

The technical inefficiency is found to be relatively more during the lean season as compared to that of the monsoon season. It further implies that even marginal holdings are relatively more efficient during the monsoon season. It also corroborates the contention that a part of the technical inefficiency among marginal holdings during the lean season is accounted for by the presence of disguised unemployment/surplus labour. The bivariate analysis of technical efficiency with the size of the paddy holding suggested that technical efficiency increases as the size of area under rice cultivation increases. It may be therefore argued that regardless of the seasons, consolidation of marginal holdings may have the potentiality of increasing actual output closer to the level of frontier output through enhancing technical efficiency.

3.3 Efficiency across Agro-climatic Zones:

An attempt is made here to examine whether there is a marked difference across agro-climatic zones for both the seasons. The entire state has been divided into six zones based on cropping pattern, soil types, rainfall, etc. The list on the zonal divisions is given in Appendix II. Table 3.3.1 shows the frequency distribution of the farms across the different zones. The primary sampling units (tehsils) are allocated to different zones in proportion to the total area of all the crops covered by the Cost of Cultivation study. The primary sampling units are then selected in each zone (stratum) with probability proportional to the area under the selected crops, and with replacement. A one-way ANOVA test is carried out to see whether there exists any significant difference in the efficiency levels across the zones (Table 3.3.2):

Table 3.3.1
FREQUENCY DISTRIBUTION OF FARMS ACROSS ZONES

Zone	Monsoon Season	Lean Season
I	17	32
II	51	28
III	26	38
IV	33	23
V	41	18
VI	11	7
Total	179	146

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).

Table 3.3.2
VARIATION OF TECHNICAL EFFICIENCY ACROSS ZONES

Monsoon Season					Lean Season				
Source	D.F	Sum of Squares	Mean Squares	F Ratio	Source	D.F	Sum of Sqs.	Mean Sum of Sqs.	F Ratio
Between Groups	5	0.26	0.05	8.178	Between Groups	5	0.55	0.11	5.82
Within Groups	173	1.11	0.01		Within Groups	140	2.64	0.02	
Total	178	1.38			Total	145	3.19		

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).
Note: D.F stands for Degrees of Freedom.
Sqs. is the abbreviation for Squares.

The calculated value of F for both the seasons being greater than the table value of F at the one per cent level of significance, it may be inferred that there is significant variation in the efficiency levels across the zones. However, as the sample size by zone is rather small, the analysis has not been extended to the zonal level.

3.4 Conclusion

The above analysis reveals the existence of a gap between the potential output as achieved by the best farmer, and the actual level of output attained by the average farmer in both seasons. The farmers are on the average found to be more efficient in the monsoon season as compared to the lean season. A comparison of technical efficiency across the different size-classes of holdings reveals that consolidation of marginal holdings may increase the scope for attaining the maximum possible output through a decline in technical inefficiency. Efficiency is also seen to vary significantly across the zones. The wide variation in the levels of technical efficiency at the farm level calls for a more disaggregated analysis at the farm-level to account for the factors influencing efficiency. This exercise is taken up in the next chapter.

CHAPTER FOUR

"Identification of the factors causing differences between best practice and individual outputs, could help policy-makers to formulate appropriate programmes to reduce such gaps."

(Kalirajan and Flinn, 1983)

DETERMINANTS OF INTER-FARM DIFFERENCES IN TECHNICAL EFFICIENCY

The analysis of technical efficiency, in the preceding chapter, indicates the presence of wide variation in the levels of technical (in)efficiency across the farms for both seasons. This chapter makes a modest attempt to identify the factors accounting for the observed inter-farm differences in technical (in)efficiency in rice cultivation. A number of factors, that may or may not be under the control of the farmers, prevent them from realising the full potential output. The existing studies on farm-specific technical efficiency suggests that there are numerous factors associated with variations in the levels of output (Kalirajan & Flinn, 1983; Kalirajan & Shand, 1985; Flinn & Ali, 1986; Jha & Rhodes, 1997) . In fact the farm-specific characteristics which influence the decision-making process at farm-level mould the behaviour and attitude of farmers towards adoption and diffusion of High-Yielding Varieties. As Stigler (1976) puts it, ".... two farmers with reasonable homogeneous land and equipment .... obtain substantially different amount of corn. ...... The farmer will differ in the art of learning things by the expected return from new knowledge - one may be planning to leave agriculture shortly - so they 'rationally' devote different amounts of resources in acquiring knowledge." It follows that inter-farm differences in output realisation depends not only on farm-specific endowments (constraints) but also on the manner in which the farm-specific endowments are put into use. Against this background, this chapter examines the impact of farm-specific endowments (constraints) and their allocations on the inter-farm differences in technical (in)efficiency.

The organisation of the chapter is as follows. Section I discusses how the farm-specific factors influence the level of technical (in)efficiency. Section II introduces the basic model for the analysis. Section III presents the regression estimates and summarises the major findings.

4.1 Determinants of Farm-Specific Technical Efficiency: A number of farm-specific factors have been considered in this study to explain the inter-farm differences in technical efficiency levels for both the seasons. They include: the total area under irrigation, the source of irrigation, the degree of fragmentation in the paddy lands, the extent of multiple cropping, the proportion of family labour hours in the total labour hours employed, the proportion of tractor power in the total farm power employed, the status of the farmer on the basis of ownership of the holding, the hours employed of power sprayers and finally the ownership of tractors employed. The rationale for selecting these variables is given below.

The area under irrigation plays an important role in the cultivation of High-Yielding Varieties. The easier access of the large farmers to irrigation resources is initially believed to aggravate the inequality between the small and large farmers (see Kurien, C. T., 1980). It thus becomes necessary to enquire as to whether the widely irrigated farms are the ones which make use of their resources efficiently. As the area irrigated turns out to be an important determinant of efficiency so also does the source of irrigation matter. Three sources of irrigation, found to be dominant in the study area, have been considered in this study. They are canal, well and tank irrigation.

Another important factor is the extent of fragmentation in the operated holding. Going by the Neo-Malthusian theories of population growth and agricultural change, deterioration in agriculture can be attributed to the negative effects of population growth through the sub-division & fragmentation of holdings and the effect of this on the agrarian structure and agrarian relations (Nair & Das, 1991). However, in the case of Tamil Nadu, though population growth was increasing at a rapid rate and the average size of cultivated holdings was declining, productivity has remained unaffected (see Nair & Das, 1991). In this context, an analysis of the relationship between efficiency and the degree of fragmentation of holdings becomes imperative. Similarly, the extent of multiple cropping may play an important role in determining the extent of productivity (Mahalingham, 1987) as well as of technical efficiency. It may so happen that farms growing more than one crop may not be uniformly efficient in the production of all the crops. The present study, thus, considers the relationship between technical efficiency and the extent of multiple cropping.

Much of the heated debates on the issue of " farm-size versus farm efficiency" in the early sixties (see Sen, 1964a; Sen, 1964b; Rao, 1966; Khusro, 1968; Rao; 1968; Lau and Yotopoulus, 1971; Sen, 1974; Rudra & Sen, 1980) were built on the argument that smaller farms tend to be more efficient as they rely more on family labour which is put to the maximum use, such that returns are maximised (see

Sen, 1964a; Sen, 1964b; Rudra & Sen, 1980). However such intense use of family labour, it has been pointed out, can be unremunerative (see Rao, 1966). The present study, thus, probes into the question of the nature of relationship between technical efficiency and the proportion of family hours in the total labour hours employed. On the same lines, the nature of organisation, such as tenurial relationships, the ownership of tractors, etc., also matter a lot in the efficient use of resources. With regard to tenurial relations, Hanumantha Rao (1966) pointed out that if there are tenurial disincentives resulting in lower input and output per acre among tenanted holdings and if the proportion of area leased in increases with size, then the decline in output per acre with size could be explained partly by the operation of tenurial disincentives. This hypothesis is tested here with regard to technical efficiency in rice cultivation. A tenurial holding here is defined as any operating unit part or whole of which has been leased in. Also, the relationship between technical efficiency and mechanisation through use of tractors has been considered. The proportion of tractor power in the total farm-power employed is also included in the analysis. Finally, the hours employed of power sprayers has been considered. Power sprayers which are used to spray pesticides has been taken as a proxy for pesticide use in the absence of information on the latter.

4.2 The Basic Model:

Having discussed the likely factors affecting farm-specific technical efficiency, the functional form with which the relationship between farm-specific technical efficiency and the probable factors is empirically tested is presented here. The functional form chosen is the linear function, expressed as[1]:

$$\hat{u} = a_o + \Sigma a_i s_i + w_i \qquad (4.2.1)$$

where;

$\hat{u}_i$ is the estimated farm-specific technical efficiency (reported in Appendix VI).

w_i is a disturbance term with normal properties; and

s_i represents the farm-specific characteristics. The selected factors are listed below:

(i) The Area Irrigated stands for the total area under irrigation. As information pertaining to irrigation is not available for individual crops, the total area irrigated is chosen as a proxy under the assumption that paddy is one of the water-intensive crops.

(ii) Fragmentation, number of plots used for paddy cultivation in a farm in the season considered is taken as the degree of fragmentation in the land where paddy is cultivated.

(iii) Multiple Cropping stands for the loss of soil nutrients through multiple cropping in the farm.

---

1 *Kalirajan and Flinn, 1983.*

(iv) Well, Canal and Tank are dummies representing the different sources of irrigation. Since there are four classifications of irrigation source, i.e., well operated farms, canal operated farms, tank operated farms and farms depending on both well and canal, three dummies representing well, canal and tank irrigation are considered. The dummy on Well takes the value of one for farms depending on well irrigation and zero otherwise. Likewise, the dummies on Canal and Tank take the value of one for farms operating on canal and tank irrigation respectively and zero otherwise.

(v) Owner cultivator, a dummy variable which takes the value of one if the whole area operated is owned and zero if any portion of the area operated is leased in.

(vi) Family hours stands for the proportion of family hours in the total labour hours employed.

(vii) Tractor hours show the proportion of tractor power in the total farm power employed.

(viii) The dummy for tractors takes the value of one if the tractor is owned and zero otherwise.

(ix) Power sprayers stands for the total hours employed of power sprayers.

4.3 The Empirical Results:

The above linear function (equation 4.2.1) is estimated in a multiple regression framework using Ordinary Least Squares (OLS) method.

Before going into the analysis of determinants it would be interesting to look into certain important characteristics which may highlight the different behaviourial patterns with regard to the use of certain inputs across the different size-classes of holdings[2] (see Bharadwaj, 1974). Table 4.3.1 shows the mean, standard deviation and co-efficient of variation of three factors, the use of which usually marks out the small farms from the large farms. These variables are the proportion of family hours in the total labour hours employed, the proportion of tractor power in the farm power used and the proportion of organic manure in total fertilizers applied.

2 *The size of the holding refers to the area under the paddy crop.*

Table 4.3.1

DISTRIBUTION OF FACTORS ACROSS SIZE-CLASSES OF HOLDINGS

MONSOON SEASON										
VARIABLES	**PRO.OF FAMILY HOURS**			**PRO.OF TRACTOR POWER**			**PRO.OF ORGANIC MANURE**			**NO. OF OBS**
Area	**Mean**	**S.D**	**C.V (%)**	**Mean**	**S.D**	**C.V (%)**	**Mean**	**S.D**	**C.V (%)**	
< 1 Hectare	0.2309	0.193	83	0.3344	0.372	111.21	0.0594	0.11	287.21	112
1 - 2 Hectares	0.1345	0.134	99.93	0.4483	0.354	78.99	0.0907	0.105	242.01	40
2 - 3 Hectares	0.0905	0.073	80.99	0.4927	0.347	70.37	0.1045	0.284	206.60	14
> 3 Hectares	0.0583	0.044	76.16	0.5185	0.382	73.60	0.0233	0.037	208.58	13
Total	0.1858	0.177	95.32	0.3856	0.370	96.01	0.0671	0.128	280.92	179

LEAN SEASON										
VARIABLES	**PRO.OF FAMILY HOURS**			**PRO.OF TRACTOR HOURS**			**PRO.OF ORGANIC MANURE**			**NO. OF OBS.**
Area	**Mean**	**S.D**	**C.V (%)**	**Mean**	**S.D**	**C.V (%)**	**Mean**	**S.D**	**C.V (%)**	
< 1 Hectare	0.2603	0.174	66.77	0.3550	0.381	107.44	0.0995	0.15	150.85	82
1 - 2 Hectares	0.1386	0.129	92.93	0.4731	0.376	79.52	0.0991	0.116	116.65	39
2 - 3 Hectares	0.1042	0.10	95.39	0.8719	0.10	11.49	0.0381	0.054	142.52	9
> 3 Hectares	0.0729	0.074	101.78	0.6899	0.417	60.44	0.0957	0.151	157.86	16
Total	0.1976	0.198	84.31	0.4551	0.399	87.76	0.0952	0.137	144.12	146

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).
Note: Pro. is the abbrievation for Proportion.
Obs. is the abbrievation for Observations.
S.D stands for Standard Deviation.
C.V stands for Co-efficient of Variation.

As is clear from Table 4.3.1, the co-efficient of variation is quite high for all the variables, the only exception being that of the co-efficient of variation in the proportion of tractor power in the total farm power employed in the category of farms cultivating within 2-3 hectares of land, implying a certain degree of uniformity in the use of tractors among the farms falling in this category. The mean values suggests that the proportion of family labour hours in the total labour hours employed decreases as the size of the cultivated area increases. On the otherhand a positive relation is observed between the area cultivated and the proportion of tractor hours in the total farm power employed. However, the proportion of organic manure in the total amount of fertilizers applied does not seem to vary much across the different size-classes of the holdings. The extent of family labour and tractor power employed is seen to be higher in the lean season as compared to the monsoon season which may be indicative of disguised unemployment/surplus labour in marginal holdings in the absence of alternative employment opportunities resulting in greater inefficiency in the use of these resources as was proved in the last chapter. The mechanisation of farm power through the use of tractors enabled the medium and large farms to attain relatively higher levels of technical efficiency.

The estimates obtained by regressing the farm-specific factors on the farm-specific levels of technical efficiency are shown in Table 4.3.2.

Table 4.3.2

DETERMINANTS OF TECHNICAL EFFICIENCY IN RICE CULTIVATION

Variable	Monsoon Season	Lean Season
Constant	0.81659 (13.897)*	0.77986 (10.338)*
Area Irrigated (in hectares)	-0.0076683 (-1.916)**	-0.000057371 (-0.525)
Fragmentation	-0.00024530 (-0.039)	-0.00059845 (-0.050)
Multiple Cropping	0.0023361 (0.356)	-0.0062224 (-0.319)
Well	-0.042164 (-0.864)	-0.027489 (-0.596)
Canal	0.0045640 (0.092)	0.060345 (1.457)
Tank	-0.0076520 (-0.147)	-0.044019 (-0.818)
Owner Cultivator	0.026778 (1.091)	-0.012149 (-0.249)
Family Hours (proportion to total hours)	-0.064731 (-1.566)	-0.085684 (-1.025)
Tractor Hours (proportion to total hours)	0.060846 (3.222)*	0.0082733 (0.218)
Tractor Ownership	0.037381 (1.274)	-0.080639 (-1.685)**
Power Sprayers	0.00076188 (0.315)	0.0083307 (1.896)**
$\bar{R}^2$	0.13	0.08

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).
Note: Figures in parenthesis are the respective t-ratios.
** Significant at one per cent level.*
*** Significant at ten per cent level.*

The value of R^2 in Table 4.3.2 reveals that very little of the variation in the efficiency levels has been explained by the fitted model for both the seasons. The analysis for the monsoon season shows technical efficiency to be negatively related to the area irrigated. This variable turns out to be significant at the ten per cent level. It implies that during the monsoon season, waterlogging could affect the level of technical efficiency at farm level, which in turn suggests that better water management practices may perhaps increase the scope for attaining higher levels of technical efficiency. Further, technical efficiency is seen to be positively related to the proportion of tractor power in the total farm power employed which strengthens the contention that mechanisation of farm power is associated with higher levels of efficiency in the larger holdings. All the other variables turn out to be insignificant.

For the lean season, it is interesting to note that of the variables considered, the ownership of tractor and the hours employed of power sprayers turn out to be significant at ten per cent level. The negative sign of the tractor co-efficient shows technical efficiency to be declining if the tractor operated is owned. This observation is not surprising in the sense that most of the marginal holdings use the hired tractor power which creates a market niche for the farm owning tractors to hire out and make money. This is also a reflection of the fragmentation of the land where raising and rather maintaining draught power is uneconomic. On the otherhand, efficiency is seen to be positively related to the hours employed of power sprayers. All the other variables turn out insignificant. The insignificance of some of these variables, such as the dummy on owner cultivator and the different sources of irrigation, may be related to the nature of sample size where most of the farms are marginal holdings which have neither excess land to lease out nor do they have resource endowments to lease in during lean season.

On the whole, it may be inferred that the sample size under study, which consists more of marginal and small holdings having more or less similar farm characteristics, regardless of the seasons, weakens the explanatory power of the model. At the same time, it may also be noted that R^2 can be closer to zero when sample size increases.

Nevertheless, the present analysis throws indirectly some insights into the factors influencing the technical efficiency at least among the marginal holdings. One of the findings is that during the monsoon season, there is a scope for farmers to increase the level of technical efficiency (the level of output) through better water management practices. The second interesting finding is that mechanisation of farm power may have contributed to the higher levels of technical efficiency among the medium and large farmers during the monsoon season. As far as the lean season is concerned, the fragmentation in land holdings must have created a market for tractor power which the medium and large farmers owning tractors take advantage of by making money from hiring out their tractors. It may be, therefore, concluded that fragmentation of land holdings, manifest in many ways, constrain the farmers from realising the maximum possible output.

CHAPTER FIVE

".....The motivation clearly is to get the best out of our national endowments and available agricultural technologies to improve the economics of the agricultural production systems, looked at in its comprehensive sense, so that not only the lot of the land-holders will improve but also the incomes of those dependent on land, particularly the landless agricultural labourers."

(Patil, 1997)

SUMMARY AND CONCLUSIONS

The present study has been carried out with the objective of examining the extent of technical (in)efficiency in rice production in Tamil Nadu for the year 1992-93. Using the production frontier methodology in the measurement of technical efficiency, the study was carried out for the two main agricultural seasons, that is the monsoon and lean seasons. The analysis was done at the farm-level making use of the Cost of Cultivation data. The study establishes the existence of a gap between the potential level of production and the level of production of the average farmer for both the seasons. The study also examined the variation in the levels of technical efficiency across the different size-classes of holdings and different zones and attempts to provide an explanation for the inter-farm differences in technical efficiency through certain farm-specific characteristics. The main findings and conclusions of the study are summarised below.

5.1 Summary of Major Findings

* The `average´ technical inefficiency is estimated to be 23 per cent and 16 per cent for the lean and monsoon seasons respectively. In otherwords, the average level of technical efficiency is 77 per cent and 84 per cent for the lean and monsoon seasons, indicating that the average farmer can produce the maximum possible output if he improves his technical efficiency in resource use by 23 and 16 per cent in the respective seasons. Thus, on the average, the farmers are found to be more efficient during the monsoon season as compared to the lean season.

* Around 46 per cent of the farmers in the lean season and 68 per cent of the farmers in the monsoon season have efficiency levels that fall within 20 per cent below the maximum output as represented by the frontier.

* Estimates of farm-specific technical efficiency levels show a variation between 30 per cent and 97 per cent and between 45 per cent and 97 per cent for the lean and monsoon seasons respectively, and so does the potential to increase farm output with the existing levels of inputs and technology.

* An ANOVA test reveals that the level of technical efficiency is significantly different between the agro-climatic Zones (classified on the basis of cropping pattern, soil type and rainfall) implying that the inter-farm differences in the level of technical efficiency is perhaps, partly the consequence of variations in agro-climatic zones.

* A comparison across different sizes of holdings shows that there is a positive association between area under cultivation and the level of technical efficiency. Besides, it is noted that the marginal holdings are the inefficient ones. This is true for both the seasons.

* The analysis on the inter-farm differences in technical efficiency revealed that very little of the variation in efficiency is explained by the selected factors. Only

two factors in each season turned out to be significant in the analysis. For the monsoon season, the factors that turned out significant were the area under irrigation and the proportion of tractor power in the total farm power employed. While efficiency was seen to be negatively related to the area under irrigation, a positive relation between technical efficiency and the proportion of tractor power in the total farm power employed was observed. The analysis for the lean season revealed that technical efficiency was related positively to the number of hours of power sprayers (used for spraying pesticides) employed and negatively with the ownership of tractors.

* The analysis brought to light certain interesting features relating to input usage in the different size-classes of the operational holdings. The marginal and small holdings were found to be characterised by disguised unemployment during the lean season, possibly due to the non-availability of alternate employment opportunities during this season. The proportion of family hours in the total labour hours employed was found, regardless of seasons, to decrease as the size of the cultivated area increased. On the otherhand, the proportion of tractor hours in the total farm power used was found to increase as the size of the cultivated area increased.

5.2 Conclusion

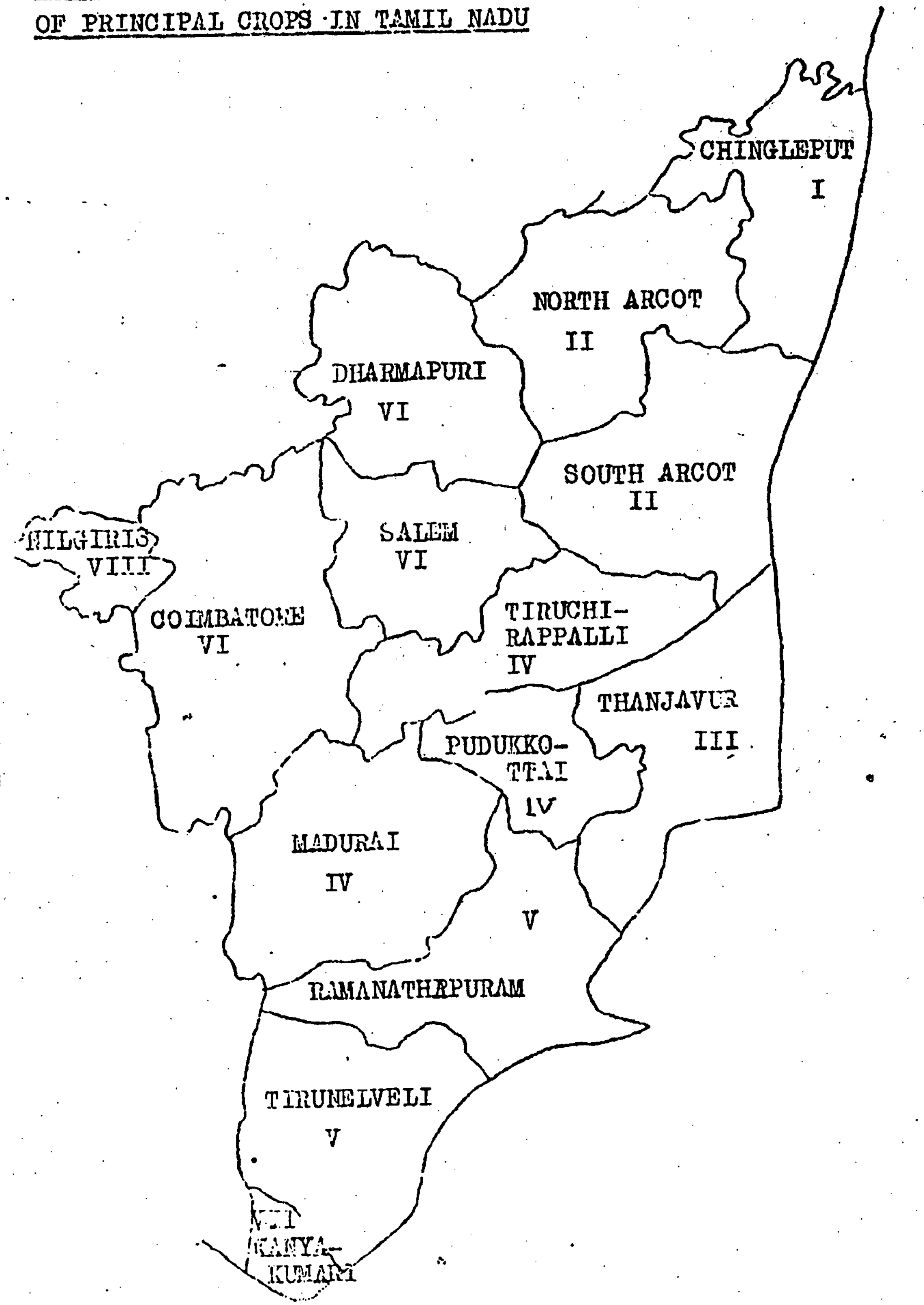
The analysis reveals that regardless of the seasons there is a further scope for increasing rice production in the State further through an improvement in average efficiency levels. This is possible through better farm management practices that would result in the better utilisation of the existing inputs. The predominance of marginal holdings in the study sample for both the seasons is suggestive of the fact that the fragmentation of holdings in itself may act as a constraint to the attainment of potential output as farm activity becomes relatively uneconomic, cost-intensive and market dependent for almost all inputs (see Ray, 1990). This point is further strengthened by the fact that the marginal holdings are found to be relatively inefficient during both the seasons. The policy implication is that there is a need for consolidation of the marginal holdings to make them economically viable and technically efficient through targeted intervention programmes. The analysis shows the area under irrigation to have a negative association with technical efficiency during the monsoon season, implying thereby that the average efficiency level in the monsoon season may be improved further through better water management practices. It may be noted that during the monsoon season, the marginal farmers may not collectively undertake the water management work, particularly the maintenance of irrigation and water channels, which may result in water logging.

Moreover, the incidence of family labour is found to be high among the marginal holdings regardless of the seasons. This itself is the manifestation of wide-spread prevalence of disguised unemployment/surplus labour which acts as a constraint on technical efficiency. This is evident in the lean season when no alternative employment opportunities are available. This highlights the need to provide alternative employment opportunities and educational facilities for the removal of illiteracy among the farmers.

In sum, the existence of a gap between the mean level of production and the potential level of production during both the seasons calls for policy initiatives in the appropriate direction which may act as incentives to the farmers for raising output to the potential level. Once the potential level has been reached, an improvement or overhauling of the existing technology through more effective research and investment in agricultural technology and infrastructure would be desirable.

APPENDIX I

COMPREHENSIVE SCHEME FOR STUDYING THE COST OF CULTIVATION OF PRINCIPAL CROPS IN TAMIL NADU



APPENDIX II

LIST OF SELECTED DISTRICTS, TALUKS AND VILLAGES

ZONE	NAME OF THE DISTRICT/ DISTRICT HEAD-QUARTER	CODE NO OF TALUK	NAME OF THE TALUK	NAME OF THE VILLAGE V-1	V-2
I.	CHENGAI-ANNA (KANCHEEPURAM-H.Q)	01	KANCHEEPURAM-I	AVALUR	
		02	KANCHEEPURAM-II	THENNERI	
		03	CHENGALPATTU	SENGUNDRAM	KONDAMANGALAM
		04	PONNERI	THADEPERUMAPAKKAM	
II.	NORTH ARCOT AMBEDKAR-DISTRICT (VELLORE-H.Q)	05	GUDIYATHAM-I	VEPPUR	
		06	GUDIYATHAM-II	KANDIPPEDU	
	SAMBUVARAYAR-DISTRICT (THIRUVANNAMALAI-H.Q)	07	CHEYYAR	PURISAI	
		08	THIRUVANNAMALAI	MANGALAM	
		09	POLUR	ARUNAGIRIMANGALAM	
II.	SOUTH ARCOT (VILLUPURAM-H.Q)	10	KALLAKURICHI	ARIYAPERUMANUR	
		11	TITTAGUDI	KILIMANAGALAM	PELANTHURAI
		12	TINDIVANAM	MELPAKKAM	
		13	VILLUPURAM	PANCHAMADEVI	
		14	GINGEE-I	VALLAM	
		15	GINGEE-II	ALAMPUNDI	
		16	GINGEE-III	AVALURPETTAI	
		17	TIRUKKOILUR	KANDACHIPURAM	
III.	THANJAVUR (THANJAVUR-H.Q)	18	KUMBAKONAM	MARUTHANALLUR	THIPPIRAJAPURAM
		19	PAPANASAM	SOOLAMANGALAM	
		20	THIRUVIDAIMARUTHUR	NARASINGAMPETTAI	SATHANCOR
		21	PATTUKOTTAI	ENADI	
		22	KUDAVASAL	SENGALIPURAM	
		23	MANNARGUDI	NEDUVAKOTTAI	
		24	VEDARANYAM	TAGATTUR	
		25	MYLADUTHURAI	CHATRAPALAPURAM	THOZHUTHALANDGUDI
IV.	MADURAI (MADURAI-H.Q)	26	MADURAI NORTH	SAMAYANALLUR	
		27	MELUR	A.VALLALAPATTI	
		28	USILAMPATTI	KOVILANGULAM	
		29	UTHAMAPALAYAM	BOOTHIPURAM	
	QUAIDE MILIETH (DINDIGUL-H.Q)	30	PALANI	VIRUPATCHI	
		31	DINDIGUL	ATTUR	
	THIRUCHIRAPALLI (TRICHY-H.Q)	32	TRICHY-I	MALLIAMBATHU	
		33	TRICHY-II	THIRUCHENDURAI	
		34	KULITHALAI	THOGAMALAI	
		35	MUSIRI	URAKKARAI	
		36	LALGUDI	PUDUKKUDI	ESANAKKORAI
IV.	PUDUKOTTAI(PUDUKOTTAI-H.Q)	37	THIRUMAYAM	PONNAMARAVATHI WEST	
		38	ARANTHANGI	AYINGUDI	
V.	RAMANATHAPURAM (RAMANATHA-PURAM-H.Q)	39	PARAMAKUDI	KAMUTHAKUDI	
V.	KAMARAJ (VIRUDHUNAGAR-H.Q)	40	SRIVILLIPUTHUR	POOVANI	SENKAPPANAICKENPATTI
		41	RAJAPALAYAM	KOVILUR	CHOCKANATHANPUTHUR
		42	ARUPUKOTTAI	KALKURICHI	

Appendix II Continued.

ZONE NAME OF THE DISTRICT/ HEAD-QUARTER	CODE NO OF TALUK	NAME OF THE TALUK	NAME OF THE VILLAGE V-1	V-2
V. NELLAIKATTAPOMMAN (THIRUNELVELI-H.Q)	43	SANKARANKOVIL	VADAKKUPATTI	
	44	TENKASI	KEELAPAVOOR	
	45	AMBASAMUDRAM	GOPALASAMUDRAM	
CHIDAMBARANAR (TUTICORIN-H.Q)	46	SRIVAIKONDAM	VITTILAPURAM	
	47	KOVILAPATTI	NALLATINPUDUR	
COIMBATORE (COIMBATORE-H.Q)	48	COIMBATORE SOUTH	DEVARAYAPURAM	
	49	UDUMALPET	JALLIPATTI	
	50	POLLACHI	PETHANAICKANUR	
	51	AVINASHI	THEKKALUR	
VI. PERIYAR (ERODE-H.Q)	52	ERODE-I	PERIYASEMUR	
	53	ERODE-II	VILAKKETHI	
	54	SATHYAMANGALAM-I	MAKKINAMKOMBAI	
	55	SATHYAMANGALAM-II	VINNAMPALLI	
	56	DHARAPURAM	MOOLANUR	
VI. SALEM (SALEM-H.Q)	57	OMALUR	KUTTAMETTUPATTI	
	58	THIRUCHENGODE	DEVANANKURUCHI	
VI. DHARMAPURI (DHARMAPURI-H.Q)	59	DHARMAPURI	SETTIKARAI	
	60	KRISHNAGIRI	KAVERIPATTNAM	

Source: Comprehensive Scheme for Studying the Cost of Cultivation of Principal Crops in Tamil Nadu for the Year 1990-93.

APPENDIX III

Details of Plot-wise Information on Crops

The plot-wise data for different crops grown over the crop year contains the following details:

Land: The area of the plot given in hectares. The farms are classified into different size classes; outlined in Chapter I. Information on the rent paid on the land, if it is leased in, and the imputed rent, in the case of land owned by the cultivator, is given separately in cash, kind as well as the total value. The land tax or cess for each plot is also given.

Energy inputs: Operation-wise data on the number of hours of human, animal and machine hours employed is provided. The human labour hours are further separated into family, permanent and casual labour categories. The wages paid to casual labour, in cash, kind and the aggregate value, for each operation is also provided. The type of machine used, such as tractor, thresher, oil engines and electric motors is identified. Where the machines and animals are hired, the hours contributed to the operation by owned and hired sources are given separately. In the case of the hired category of machine and animal hours, the value of the hours employed, both in cash and kind as well as the aggregate value, is provided.

Material Inputs: The use of seeds, organic manure and chemical fertilizers is given in physical as well as value units. The quantity of chemical fertilizers is separated out into Nitrogen, Phosphorus and Potassium units; the value given is the aggregate of all three types of fertilizers.

Output: Data on the main product, by-product and the total product (which represents the main product and by-product taken together), is given separately for each plot, both in physical and value terms.

Irrigation: The data set also contains information on the source of irrigation and the irrigation charges. In the latter case the information pertains only to those plots owned by the farmer.

Besides plot-wise information, the data set also contains information relating to the entire farm, such as the value of the buildings, machines and other stocks, the area under irrigation, the number and literacy levels of the family members in the farm household, etc.

APPENDIX IV

F-Test: Provides a general method of testing hypothesis about one or more parameters in a multiple regression model. In this case the null hypothesis is that all the interaction terms (that is, β_{ij} in equation 3.11) are equal to zero. The F-test is expressed as:

$$F = \frac{R^2_{UR} - R^2_{R}/m}{(1-R^2_{UR})/(n-k)}$$

where; R^2_{UR} is the explained sum of squares from the unrestricted model and R^2_{R} that of the restricted model, m is the number of regressors assumed to be absent from the model (that is, all β_{ij}), n is equal to the total number of observations and k is the total number of parameters specified. The results of the test on the data sets relating to the monsoon and lean seasons are shown below:

Monsoon season:

$$F = \frac{0.9612919 - 0.9612827/15}{1 - 0.9612919/179 - 21} = \frac{0.0000092/15}{0.0387081/158}$$

$$= 0.0024499$$

Lean season:

$$F = \frac{0.9532899 - 0.9527701/5}{1 - 0.9532899/146-21} = \frac{0.0005198/15}{0.0467101/125}$$

$$= 0.092734177$$

As the calculated value of F turns out lesser than the tabulated value of F at the one per cent level of significance at (15, 158) and (15,125) degrees of freedom for the monsoon and lean season respectively, the null hypothesis that the interaction terms equals zero is found to be valid in both the cases.

APPENDIX V

Calculation of *Population* `Average' Technical Inefficiency and Variance-Ratio Parameter:

ESTIMATES OF VARIANCE: Error Term Components

	Monsoon Season	**Lean Season**
σ^2_u	0.04	0.081
σ^2_v	0.026	0.004
$\sigma = \sigma^2_u + \sigma^2_v$	0.07	0.085
σ^2_u/σ	0.60	0.95
σ_u/σ_v	1.23	4.57

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).

In the above table σ^2_u stands for the variance of the technical efficiency component of the error term. The variance of the random error component is given by σ^2_v. The sum of the two variances, i.e. $\sigma^2_u + \sigma^2_v$, is denoted by σ. The ratio σ^2_u/σ shows the proportion of the variation in total output from the maximum possible output due to variation from technical (in)efficiency alone. This ratio is known as the variance ratio parameter. The ratio σ_u/σ_v is the ratio of the standard deviation of the technical efficiency parameter to that of the random error component.

From the estimate of the variance of the technical efficiency parameter the *population* `average' technical inefficiency is calculated by $-\sigma_u\sqrt{2/\pi}$. This takes the value of 0.16 and 0.23 for the monsoon and lean seasons respectively.

APPENDIX VI

FARM-SPECIFIC ESTIMATES OF TECHNICAL EFFICIENCY (e^{-u_i}) ACROSS ZONES

ZONE	LEAN SEASON	MONSOON SEASON
1	Ø.94ØØ97	Ø.8ØØ1Ø5
1	Ø.663695	Ø.869776
1	Ø.9Ø7Ø16	Ø.821461
1	Ø.8713Ø7	Ø.839314
1	Ø.622546	Ø.8721Ø4
1	Ø.899938	Ø.756789
1	Ø.938586	Ø.617446
1	Ø.9Ø9433	Ø.826247
1	Ø.897Ø61	Ø.6189Ø2
1	Ø.6ØØ679	Ø.7Ø8494
1	Ø.338Ø24	Ø.61136
1	Ø.488884	Ø.724189
1	Ø.613688	Ø.787283
1	Ø.577682	Ø.7149Ø8
1	Ø.552442	Ø.799254
1	Ø.49382	Ø.716Ø39
1	Ø.541Ø8	Ø.847Ø5
1	Ø.574431	-
1	Ø.546345	-
1	Ø.6Ø835	-
1	Ø.571199	-
1	Ø.534356	-
1	Ø.349879	-
1	Ø.87Ø564	-
1	Ø.6718Ø1	-
1	Ø.787393	-
1	Ø.927954	-
1	Ø.395396	-
1	Ø.894673	-

Appendix VI Continued.

ZONE	LEAN SEASON	MONSOON SEASON
1	Ø.769655	-
1	Ø.787525	-
1	Ø.689497	
Mean	Ø.68	Ø.76
S.D.	Ø.184	Ø.Ø87
C.V.(%)	27	11
2	Ø.628966	Ø.8923Ø7
2	Ø.778515	Ø.779134
2	Ø.64Ø56	Ø.82Ø881
2	Ø.9Ø34Ø5	Ø.847811
2	Ø.654522	Ø.848Ø64
2	Ø.614138	Ø.658853
2	Ø.3Ø1637	Ø.742421
2	Ø.627316	Ø.5344Ø9
2	Ø.37Ø769	Ø.741Ø7
2	Ø.7ØØ286	Ø.824594
2	Ø.7ØØ463	Ø.694127
2	Ø.748Ø89	Ø.7162Ø7
2	Ø.727776	Ø.748894
2	Ø.816496	Ø.777662
2	Ø.745232	Ø.8ØØ552
2	Ø.681Ø13	Ø.76Ø916
2	Ø.93Ø856	Ø.658326
2	Ø.521666	Ø.757883
2	Ø.911666	Ø.793175
2	Ø.743848	Ø.777569
2	Ø.623978	Ø.87411
2	Ø.8248Ø9	Ø.96363
2	Ø.814528	Ø.899623

Appendix VI Continued.

ZONE	LEAN SEASON	MONSOON SEASON
2	Ø.627258	Ø.883588
2	Ø.97Ø188	Ø.7Ø5Ø28
2	Ø.666183	Ø.881114
2	Ø.586676	Ø.8836
2	Ø.76Ø351	Ø.898411
2	-	Ø.92469
2	-	Ø.927884
2	-	Ø.848795
2	-	Ø.753981
2	-	Ø.89559
2	-	Ø.848975
2	-	Ø.784373
2	-	Ø.779346
2	-	Ø.8869Ø3
2	-	Ø.7453Ø1
2	-	Ø.772255
2	-	Ø.792321
2	-	Ø.695969
2	-	Ø.839218
2	-	Ø.86Ø716
2	-	Ø.877492
2	-	Ø.726Ø82
2	-	Ø.714Ø96
2	-	Ø.87Ø179
2	-	Ø.633725
2	-	Ø.881822
2	-	Ø.882713
2	-	Ø.911Ø23
Mean	Ø.7	Ø.76
S.D.	Ø.151	Ø.884
C.V.(%)	22	116

Appendix VI Continued.

ZONE	LEAN SEASON	MONSOON SEASON
3	Ø.821274	Ø.87Ø288
3	Ø.8Ø1ØØ8	Ø.83616
3	Ø.9159Ø3	Ø.861534
3	Ø.854329	Ø.926884
3	Ø.924679	Ø.8Ø6Ø69
3	Ø.867472	Ø.896641
3	Ø.869953	Ø.729317
3	Ø.9Ø2ØØ3	Ø.838659
3	Ø.91257	Ø.894899
3	Ø.868891	Ø.87Ø186
3	Ø.63795	Ø.9257Ø5
3	Ø.6357Ø5	Ø.855Ø95
3	Ø.786Ø44	Ø.817413
3	Ø.945699	Ø.816735
3	Ø.958217	Ø.85Ø964
3	Ø.872683	Ø.844221
3	Ø.9Ø1678	Ø.8Ø2662
3	Ø.86Ø727	Ø.9ØØ9Ø4
3	Ø.941Ø95	Ø.836847
3	Ø.7Ø1689	Ø.831215
3	Ø.7Ø8879	Ø.896449
3	Ø.71217	Ø.826Ø47
3	Ø.684Ø81	Ø.882649
3	Ø.642234	Ø.864733
3	Ø.65849	Ø.8321Ø5
3	Ø.672458	Ø.823565
3	Ø.935154	-

Appendix VI Continued.

ZONE	LEAN SEASON	MONSOON SEASON
3	Ø.967439	-
3	Ø.698728	-
3	Ø.679293	-
3	Ø.595345	-
3	Ø.7118Ø7	-
3	Ø.677335	-
3	Ø.59Ø449	-
3	Ø.751456	-
3	Ø.682Ø38	-
3	Ø.679187	-
3	Ø.645331	-
Mean	Ø.78	Ø.85
S.D.	Ø.12	Ø.Ø43
C.V.(%)	15	5
4	Ø.64518	Ø.875Ø7
4	Ø.78Ø935	Ø.9Ø5778
4	Ø.837856	Ø.778195
4	Ø.89Ø824	Ø.938922
4	Ø.865962	Ø.573172
4	Ø.744732	Ø.9Ø6475
4	Ø.675652	Ø.926614
4	Ø.962947	Ø.9Ø4Ø45
4	Ø.959999	Ø.846934
4	Ø.949264	Ø.893445
4	Ø.961827	Ø.812438
4	Ø.966349	Ø.8919Ø2
4	Ø.958Ø52	Ø.86Ø136
4	Ø.849452	Ø.878659
4	Ø.828271	Ø.835Ø69

Appendix VI Continued.

ZONE	LEAN	MONSOON
4	Ø.658Ø79	Ø.86873
4	Ø.944878	Ø.837899
4	Ø.79ØØ71	Ø.8278Ø2
4	Ø.5635Ø7	Ø.87713
4	Ø.863124	Ø.8449Ø5
4	Ø.826318	Ø.821113
4	Ø.776Ø8	Ø.584427
4	Ø.787296	Ø.759Ø58
4	-	Ø.943739
4	-	Ø.88246
4	-	Ø.818237
4	-	Ø.892666
4	-	Ø.82296
4	-	Ø.781843
4	-	Ø.834445
4	-	Ø.8Ø8553
4	-	Ø.781692
4	-	Ø.7833Ø8
Mean	Ø.83	Ø.84
S.D.	Ø.116	Ø.Ø82
C.V.(%)	14	1Ø
5	Ø.898359	Ø.8Ø5836
5	Ø.897952	Ø.657499
5	Ø.91Ø127	Ø.79Ø713
5	Ø.88Ø437	Ø.743461
5	Ø.846449	Ø.862974
5	Ø.823858	Ø.877356
5	Ø.824216	Ø.819579
5	Ø.81646	Ø.81351

Appendix VI Continued.

ZONE	LEAN	MONSOON
5	Ø.783548	Ø.77Ø749
5	Ø.75Ø132	Ø.839354
5	Ø.791247	Ø.757336
5	Ø.8357Ø6	Ø.918399
5	Ø.861994	Ø.72826
5	Ø.581243	Ø.878Ø95
5	Ø.79678	Ø.9Ø2618
5	Ø.7655Ø1	Ø.91Ø2Ø6
5	Ø.9Ø7883	Ø.912481
5	Ø.6653	Ø.899271
5	-	Ø.9ØØ492
5	-	Ø.9Ø8438
5	-	Ø.843269
5	-	Ø.9Ø2894
5	-	Ø.881916
5	-	Ø.885847
5	-	Ø.8969Ø6
5	-	Ø.86Ø1Ø1
5	-	Ø.827176
5	-	Ø.792497
5	-	Ø.871Ø42
5	-	Ø.814191
5	-	Ø.847137
5	-	Ø.89Ø53
5	-	Ø.863518
5	-	Ø.9Ø8639
5	-	Ø.887438
5	-	Ø.861737
5	-	Ø.831521

Appendix VI Continued.

ZONE	LEAN	MONSOON
5	-	Ø.8Ø78Ø1
5	-	Ø.862316
5	-	Ø.892537
5	-	Ø.821952
Mean	Ø.81	Ø.85
S.D.	Ø.Ø86	Ø.Ø58
C.V.(%)	11	7
6	Ø.958993	Ø.626366
6	Ø.917863	Ø.734693
6	Ø.813181	Ø.887685
6	Ø.865648	Ø.746685
6	Ø.893211	Ø.865218
6	Ø.816855	Ø.698967
6	Ø.854225	Ø.511789
6	-	Ø.635Ø76
6	-	Ø.845965
6	-	Ø.459ØØ5
6	-	Ø.827812
Mean	Ø.87	Ø.71
S.D.	Ø.Ø53	Ø.143
C.V.(%)	6	2Ø

Source: Cost of Cultivation Data for Tamil Nadu (1992-93).

SELECTED BIBLIOGRAPHY

Acharya, Sarthi (1995), "**Some Aspects of Indian Agriculture: An Analysis Based on Cost of Cultivation Studies for the 1980s in India**", Monograph No. 108, The Hague: Institute of Social Studies.

Afriat, S.N. (1972), "Efficiency Estimation of Production Functions", **International Economic Review**, Vol.13, No.3, October, pp. 568-98.

Agarwal, R.N. and B.N. Goldar (1992), "Technical Efficiency in the Indian Engineering Industry: Deterministic Vs. Stochastic Frontier Production Function Approach, **Institute of Economic Growth**, No. E/151/92.

Aigner, D.J. and S.F. Chu (1968), "On Estimating the Industry Production Function", **American Economic Review**, Vol. 58, No. 4, September, pp. 826-839.

Aigner, D.J, C.A.K. Lovell and Peter Schmidt (1977), "Formulation and Estimation of Stochastic Frontier Production Function Models", **Journal of Econometrics**, Vol.6, No.1, July, pp. 21-37.

Ali, M. and M.A. Chaudhry (1990), "Inter-regional Farm Efficiency in Pakistan's Punjab: A Frontier Production Function Study", **Indian Journal of Agricultural Economics**, Vol.41, No.1, pp. 62-73.

Andrew, Scott (1996), Appropriate Technology. Is It Ready for -- and Relevant to -- the Millennium?, **Appropriate Technology**, Vol.23, No.3, December, London: Intermediate Technology Publications Ltd.

Battese, G.E., T.J. Coelli and T.C. Colby (1989), "Estimation of Frontier Production Functions and the Efficiencies of Indian Farms Using Panel Data from ICRISAT'S Village Level Studies", **Journal of Quantitative Economics**, Vol. 5, No. 2, July, pp. 327-343.

Bauer, P.W. (1990), "Recent Developments in the Econometric Estimation of Frontiers", **Journal of Econometrics**, 46, No.1/2, October/November, pp.39-56.

Belsley, A.D. (1991), **Conditioning Diagnostics: Collinearity and Weak Data in Regression**, New York: John Wiley & Sons, Inc.

Bhalla, G.S. and D.S. Tyagi (1989a), "Spatial Pattern of Agricultural Development in India", **Economic and Political Weekly**, Vol. XXIV, No. 25, June 24, pp. A-46 - A-56.

Bhalla, G.S. and D.S. Tyagi (1989b), "**Patterns in Indian Agricultural Development: A District Level Study**", New Delhi: Institute for Studies in Industrial Development.

Bharadwaj, Krishna (1974), "**Production Conditions in Indian Agriculture: A Study based on Farm Management Surveys**", London: Cambridge University Press.

Bhatt, S.C. (1997), "**The Encyclopedic District Gazetteers of India**", Vol.2, New Delhi: Gyan Publishing House, pp. 961-1301.

Bhavani, T.A. (1990), "Technical Efficiency in Indian Modern Small Scale Sector: An Application of Frontier Model", **Institute of Economic Growth**, No. E/144/90.

Bravo-Ureta, B.E. and Laszlo Rieger (1991), "Dairy Farm Efficiency Measurement Using Stochastic Frontiers and Neoclassical Duality", **American Journal of Agricultural Economics**, Vol. 73, No. 2, May, pp. 421-428.

Broek, Julien van den, F.R. Forsund, Lennart Hjalmarsson and Wim Meeusen (1980), "On the Estimation of Deterministic and Stochastic Frontier Production Functions: A Comparison", **Journal of Econometrics** , Vol. 13, No.1, May, pp. 117-138.

Chinnappa, B.N. (1977), "Adoption of the New Technology in North Arcot District" in B. H. Farmer (ed.): **Green Revolution? Technology and Change in Rice Growing Areas of Tamil Nadu and Sri Lanka,** London: The Macmillan Press Ltd.

Das, Abhiman (1997), "Technical, Allocative and Scale Efficiency of Public Sector Banks in India", **Reserve Bank of India Occasional Papers**, Vol.18, Nos.2 & 3, Special Issue (June & Sept.), pp. 279-301.

Fan, Shenggen (1991), "Effects of Institutional Reform and Production Growth in Chinese Agriculture", **American Journal of Agricultural Economics**, Vol. 73, No. 2, May, pp. 266-275.

Farmer, B.H., C.M. Madduma Bandara, V. Shanmuga Sundaram and W.P.T. Silva (1977), "Setting the Stage" in B. H. Farmer (ed.): **Green Revolution? Technology and Change in Rice Growing Areas of Tamil Nadu and Sri Lanka,** London: The Macmillan Press Ltd.

Farrell, M.J. (1957), "The Measurement of Productive Efficiency", **Journal of the Royal Statistical Society,** Vol.120, Series A (General), Part III, pp. 253-281.

Farrell, M.J. and M. Fieldhouse (1962), "Estimating Efficient Production Under Increasing Returns to Scale", **Journal of the Royal Statistical Society,** Vol. 125, Series A, Part II, pp. 252-267.

Flinn, J.C. and Mubarik Ali (1986), "Technical Efficiency in Basmati Rice Production", **Pakistan Journal of Applied Economics,** Vol. V, No. 1, Summer, pp. 63-79.

Forsund, R., Flinn and Lennart Hjalmarsson (1974), "On the Measurement of Productive Efficiency", **Swedish Journal of Economics,** Vol. 76, pp. 141-154.

Forsund, F.R., C.A.K Lovell and Peter Schmidt (1980), " A Survey Of Frontier Production Functions And Of Their Relationship To Efficiency Measurement", **Journal of Econometrics** , 13, No.1, May, pp. 5-25.

Fuss, Melvyn and Daniel McFadden (1978), "**Production Economics: A Dual Approach to Theory and Applications,** Vol 1 & 2, Amsterdam: North-Holland Publishing Company.

Grabowski, Richard and C. Pasurka (1958), "The Technical Efficiency of Japanese Agriculture, 1878-1940", **Developing Economies**, Vol. 26, No. 2, June.

Greene, W.H. (1993), "The Econometric Approach to Efficiency Analysis" in Fried, H.O., C.A.K. Lovell and S.S. Schmidt (eds): **The Measurement of Productive Efficiency: Techniques and Applications**, New York: Oxford University Press, pp. 69-119.

Gujarati, D.N. (1995), **Basic Econometrics**, Third Edition, Singapore: McGraw-Hill, Inc.

Hall, Margaret (1959), "The Ambiguous Notion of Efficiency", **Economic Journal**, Vol. 69, March, pp. 71-86.

Harriss, John (1977), "The Limitations of HYV Technology in North Arcot District: the View from a Village", in B. H. Farmer (ed.): **Green Revolution? Technology and Change in Rice Growing Areas of Tamil Nadu and Sri Lanka**, London: The Macmillan Press Ltd.

Hati, Ashok Kumar and Ashok Rudra (1973), "Calculation of Efficiency Indices of Farmers: A Numerical Exercise", **Economic and Political Weekly**, March, pp. A17 - A20.

Heady, E.O., and J.L. Dillon (1969), " **Agricultural Production Functions**", Iowa: Iowa State University Press.

Huang, J.C and F.S. Bagi (1984), "Technical Efficiency on Individual Farms in Northwest India", **Southern Economic Journal**, Vol.51, No.1, pp. 108-15.

Iyengar, Asha(1991), **Groundnut Economy of Tamil Nadu: A Study of Spatial and Temporal Variations in Production and Productivity**, Unpublished Doctoral Thesis, Madras Institute of Development Studies, University of Madras.

James, A.J. (1996a), "Theories, Practice and Problems of Single-Equation Stochastic Frontier Function Estimation of Technical Efficiency in Cross-Sectional Data: An Application to Punjab Wheat Farmers", Working Paper Series, **Institute of Economic Growth**, No. E/175/96.

James, A.J.(1996b), "Technical and Allocative Efficiency in Punjab Wheat (1981-82 to 1985-86): A System-Based Analysis Using A Frontier Production Function", Working Paper Series, **Institute of Economic Growth**, No. E/176/96.

Jha, Raghbendra and M.J. Rhodes (1997), "**Technical Efficiency, Farm Productivity and Farm Size in Indian Agriculture**", Mumbai: Indira Gandhi Institute of Development Research.

Jhonston, J. (1991), **Econometric Methods**, Singapore: McGraw-Hill, Inc.

Jondrow, James, C.A.K. Lovell, I.S. Materov and Peter Schmidt (1982), "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model", **Journal of Econometrics**, 19, pp. 233-238.

Junankar, P.N. (1980), "Tests of the Profit-Maximisation Hypothesis: A Study of Indian Agriculture", **The Journal of Development Studies**, Vol.16, No.2, January, pp. 186-203.

Kalirajan, K. (1980), "Benefits from the High-Yielding Varieties Programme and Their Distribution in an Irrigated Paddy Area", **Indian Journal of Agricultural Economics**, Vol. XXXV, No.3, July-September.

Kalirajan, K. (1980), "The Contribution of Location Specific Research to Agricultural Productivity", **Indian Journal of Agricultural Economics**, Vol. XXXV, No. 4, October-December, pp. 8-16.

Kalirajan, K. (1981), "The Economic Efficiency of Farmers Growing High Yielding, Irrigated Rice in India, **American Journal of Agricultural Economics**, Vol. 63, No. 3, pp. 566-570.

Kalirajan, K.P. and J.C. Flinn (1983), "The Measurement of Farm-Specific Technical Efficiency", **Pakistan Journal of Applied Economics**, Vol.II, No.2, pp. 167-180.

Kalirajan, K.P. and R.T. Shand (1985), "Types of Education and Agricultural Productivity: A Quantitative Analysis of Tamil Nadu Rice Farming", **The Journal of Development Studies**, Vol.21, No. 2, January, pp. 232-243.

Kalirajan, K.P and R.T Shand (1994), "**Economics in Disequilibrium: An Approach From The Frontier**", New Delhi: Macmillan India Limited.

Kalirajan, K. P., M. B. Obwona and S. Zhao (1996), "A Decomposition of Total Factor Productivity Growth: The Case of Chinese Agricultural Growth Before and After Reforms", **American Journal of Agricultural Economics**, Vol. 78, No. 2, May.

Khusro, A. M (1968), "Returns to Scale in Indian Agriculture" in A. M. Khusro (ed.), **Readings in Agricultural Development**, Bombay: Allied Publishers.

Kumar, Praduman and M.W. Rosegrant (1994), "Productivity and Sources of Growth for Rice in India", **Economic and Political Weekly**, Vol. XXIX, No. 53, December 31, pp. A-183 - A-188.

Kumar Praduman (1996), "Agricultural Productivity and Food Security in India: Implications for Policy", **Agricultural Economics Research Review**, Vol. 9, No. 2, pp. 128-141.

Kutaula, S.S. (1993), "Application of Frontier Technology to Wheat Crop Grown on Reclaimed Soils", **Indian Journal of Agricultural Economics**, Vol.48, No.2, April-June, pp. 226-236.

Kurien, C.T. (1980), "Dynamics of Rural Transformation: A Case Study of Tamil Nadu", **Economic and Political Weekly**, Vol. XV, No. 5, 6 & 7, February, pp. 365-390.

Lau, L.J. and P.A. Yotopoulos (1971), "A Test for Relative Efficiency and Application to Indian Agriculture", **The American Economic Review**, Vol. LXI, No. 1, March, pp. 94-108.

Leibenstein, Harvey (1966), "Allocative Efficiency vs. 'X-Efficiency'", **The American Economic Review**, Vol. LVI, No. 3, June, pp. 392-415.

Lovell, C.A.K. (1993), "Production Frontiers and Productive Efficiency" in H.O. Fried, C.A.K. Lovell and S.S. Schmidt (eds): **The Measurement of Productive Efficiency: Techniques and Applications**, New York: Oxford University Press, Inc., pp. 3-67.

Maddala, G.S. and R.P.H. Fishe (1994), "Technical Change, Frontier Production Functions and Efficiency Measurement" in G. S. Maddala (ed.): **Econometric Methods and Applications**, Vol. I, England: Edward Edgar Publishing Limited.

Mahalingam, Sudha (1987), "**Instability in Tamil Nadu Agriculture: An Interdistrict Analysis of Paddy and Millets - 1951-52 to 1982-83**", Unpublished M.Phil Dissertation, Jawaharlal Nehru University, New Delhi.

Meusen, W. and J. van den Broeck (1977), 'Efficiency Estimation from Cobb Douglas Production Functions with Composed Error', **International Economic Review**, Vol. 18, No. 2, June, pp. 435-444.

Nagaraj, K. (1998), "**The Tamil Nadu Economy**", Madras Institute of Development Studies, Unpublished Monograph.

Nair, K.N. and A.C. Dhas (1991), "Agricultural Change in Tamil Nadu :1918-55" in Sabyasachi Bhattacharya et al (ed): **The South Indian Economy: Agrarian Change, Industrial Structure, and State Policy c. 1914-1947**, Oxford University Press, Delhi, 1991.

Neff, D.L., P. Garcia and C.H. Nelson (1993), "Technical Efficiency: A Comparison of Production Frontier Methods", **Journal of Agricultural Economics**, Vol. 44, No. 3, September, pp. 479-489.

Nelson, R.R (1981), "Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures", **Journal of Economic Literature**, Vol. XIX, September, pp. 1029-1064.

Nirmala, V. (1992), "**Economic Analysis of Rice Cultivation: A Study of Tamil Nadu**", New Delhi: Concept Publishing Company.

Panda, R.C. (1996), "Efficiency and Productivity - The Case of Sericulture Farms in Tamil Nadu", **Indian Journal of Agricultural Economics**, Vol. 51, No. 3, July-September.

Patil, Jayant (1997), "Long Term Challenges to Indian Agriculture" in V.S. Vyas and Pradeep Bhargava (ed.): **Policies for Agricultural Development**, Jaipur: Rawat Publications, pp. 14-29.

Ram, G.S. (Undated), "Data Relating to Cost of Cultivation Surveys", Ministry of Agriculture, Government of India, New Delhi.

Rao, Hanumantha C. H. (1966), "Alternative Explanations of the Inverse Relationship between Farm Size and Output Per Acre in India", **The Indian Economic Review**, Vol. 1, No. 2, October, pp. 1-12.

Rao, Hanumantha C.H. (1968), "Production Functions for Hyderabad Firms" in A. M. Khusro (ed.): **Readings in Agricultural Development,** Bombay: Allied Publishers.

Ray, S.K. (1990), "Small Farm Development", **Institute of Economic Growth,** No. E/143/90.

Rosegrant, M. W and R.E. Evenson (1992), "Agricultural Productivity and Sources of Growth in South Asia", **American Journal of Agricultural Economics,** Vol.74, No.3, August, pp. 757-761.

Rudra, Ashok (1967), "**Measurement in Economics**", A. N. Sinha Institute of Social Studies, Monograph 1, Calcutta: Allied Publishers.

Rudra, Ashok and Amartya Sen (1980), "Farm-Size and Labour Use: Analysis and Policy", **Economic and Political Weekly,** Vol. XV, No. 5, 6 & 7, February, pp. 391-394.

Rudra, Ashok (1982), "**Indian Agricultural Economics: Myths and Realities**", New Delhi: Allied Publishers.

Sawant, S.D. and C.V. Achuthan (1995), "Agricultural Growth across Crops and Regions: Emerging Trends and Patterns", **Economic and Political Weekly,** Vol. XXX, No. 12, March 25, pp. A-2 - A-13.

Sawant, S.D. (1997), "Performance of Indian Agriculture with Special Reference to Regional Variations", **Indian Journal of Agricultural Economics,** Vol. 52, No. 3, July-September, pp. 353-373.

Schmidt, Peter (1976), "On the Statistical Estimation of Parametric Frontier Production Functions", **The Review of Economics and Statistics,** Vol.LVIII, No.2, May, pp. 238-239.

Schultz, T. W. (1978), "**Distortions of Agricultural Incentives**", Bloomington: Indianna University Press.

Season and Crop Report of Tamil Nadu: 1992-93, Tamil Nadu: Department of Statistics.

Selvaraj, K.N., S. Krishnamoorthy & K.R Sundaravaradarajan (1998), "Is Productivity A Major Factor for Agricultural Growth? - A Regional Analysis", **Productivity,** Vol. 38, No. 4, January-March, pp. 641-652.

Selvarajan, S. and A. Ravishankar (1996), "Foodgrain Production and Consumption in India: Shifts, Trends and Implications for Food Security", **Agricultural Economics and Research Review,** Vol. 9, No. 2, pp.142-155.

Sen, A.K. (1964), "Size of Holdings and Productivity", **The Economic Weekly,** Annual Number, February, pp. 323-326.

Sen, A.K. (1964), "Size of Holdings and Productivity: A Reply, **The Economic Weekly,** May 2.

Sen, Bandhudas (1974), "**The Green Revolution in India: A Perspective**", New York: Halsted Press.

Singh, I.J., K.N. Rai and J.C. Karwasra (1997), "Regional Variations in Agricultural Performance in India, **Indian Journal of Agricultural Economics**, Vol. 52, No. 3, July-September, pp. 374-386.

Stigler, G.H. (1976), "The Existence of X-Efficiency", **American Economic Review**, Vol. 66, No. 1, March, pp. 213-216.

Tamil Nadu - An Economic Appraisal 1995-96, Chennai: Evaluation and Applied Research Department, Government of Tamil Nadu.

Timmer, C.P. (1971), "Using a Probabilistic Frontier Production Function to Measure Technical Efficiency", **Journal of Political Economy**, Vol.79, No.4, July/August, pp. 776-793.

Varadarajan, S. (1993), "Methodology for Estimating Cost of Production of Crops: A Few Issues", in U. Sankar and T. Lakshmanasamy (eds): **Methodology of Applied Economic Research**, New Delhi: Sterling Publishers Private Limited, pp. 237-245.

Varagunasingh, T.V. (1993), "Production Functions for Applied Economic Research", in U. Sankar and T. Lakshmanasamy (eds): **Methodology of Applied Economic Research**, New Delhi: Sterling Publishers Private Limited, pp. 201-216.

Verma, N.B. and R.R. Mishra (1997), "Crop Diversification and Related Issues on Small Farms in North Bihar", **Agricultural Situation in India**, Vol. 56, No. 4,n, July, pp.181-185.

Wilson, Gordon (1996), "Intervening for Technological Capability", **Appropriate Technology**, Vol.23, No.3, December, London: Intermediate Technology Publications Ltd.