

**ASSESSMENT OF ECONOMIC EFFICIENCY :  
AN APPLICATION TO PADDY CULTIVATION  
IN TAMIL NADU**

**BY**

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## CERTIFICATE

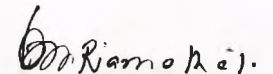
This is to certify that the thesis entitled ASSESSMENT OF ECONOMIC EFFICIENCY : AN APPLICATION TO PADDY CULTIVATION IN TAMIL NADU submitted to the Avinashilingam Institute for Home Science and Higher Education for Women (Deemed University), Coimbatore, for the award of the Degree of Doctor of Philosophy in Economics is a record of original work done by Tmt.K.M.Ramathal, Senior Deputy Registrar, Bharathiar University, Coimbatore, under my supervision and guidance and the thesis has not formed the basis for the award of any Degree/ Diploma / Associateship / Fellowship of similar title of any candidate of any University.

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Signature of the Guide

## DECLARATION

I hereby declare that the matter embodied in the thesis entitled 'Assessment of Economic Efficiency: An Application to Paddy Cultivation in Tamil Nadu' is the result of investigation carried out by me in Avinashilingam Institute for Home Science and Higher Education for Women (Deemed University), Coimbatore, under the supervision of Dr.G.Ramathilagam, M.A., M.Phil., Dip. Ed., Ph.D., Dean-Faculty of Humanities and Professor and Head, Department of Economics, Avinashilingam Institute of Home Science and Higher Education for Women (Deemed University), Coimbatore and it has not been submitted for the award of any Degree / Diploma / Associateship/ Fellowship of any other University or Institute.

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# Introduction

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## *I. Introduction*

Agriculture is the key sector of the Indian economy. Besides being the source of foodgrains and raw materials, it supports a disproportionately large percentage of work force, still it has not become strong enough to generate a surplus. The country has achieved a delicate food supply demand balance producing about 185 million tonnes of food grains for a population of 916 million which gives a per-capita availability of food grains of 498 grams per day (Govt. of India 1997).

In the Post-Green Revolution period the annual growth of food grains production was 2.62 percent, a little above the rate of population growth. Since 1981 the growth of paddy production has significantly risen to match the growth rate in wheat production. About sixty nine percent of area was under paddy cultivation with high yielding varieties ( 28.9 million ha. ) in 1993-'94 (Govt. of India 1996).

India is endeavoring to achieve optimum food production with the available technology and resources. Ali and Chaudhry (1990) maintain that efficiency is a very important factor of productivity growth in developing agricultural economies where the resources are meagre and farmers are yet to exploit fully the available technology and the opportunities for developing and adopting better methods.

The Green Revolution marking the shift of Indian farming to scientific agriculture took place in India in the late 1960s and 1970s. It offered to the farmers an opportunity to shift to high yielding varieties promising significant increase in food production and thereby the farm profits and income. Alagh (1998) states that India is the second country in the world to have a hybrid variety of paddy programme that has been transferred to the farmer's field. He commends the Indian scientists for having released 1125 varieties of cereals, 406 pulse varieties and 641 varieties of oil seeds, fibre and fodder crops. According to Swaminathan (1998), the advent of scientific agriculture has changed the image of India from one of a basket case in relation to agricultural capability into one of a bread basket capable of becoming a major agricultural power in the world. The research carried out on the adoption of new technology in crop production indicated that these technologies were scale neutral and could be adopted equally on small farms as on large farms. In practice, however, the benefits of technology were largely enjoyed by the farmers who could mobilise credit and other necessary supporting services better than the small farmers. In other words, it ceased to be scale neutral to small farmers.

The Indian agricultural sector has had the benefit of one of the biggest extension services network in the world, to disseminate among the farmers the latest advances in technology of crop cultivation. The

research had indicated that there was a positive correlation between technical efficiency and access to the extension services in developing countries (Kalirajan 1991). Yet the mute question is: Have the farmers fully utilised the potentials of new technology to generate larger output, maximum profits and income for themselves?. Earlier Kalirajan (1991) had also raised the issue of whether the potential of Green Revolution had been exploited fully by the farmers.

Feder et al.,(1985) observed that unless the potential of an existing technology is completely exploited, benefits from such technologies may not be as expected. Kalirajan (1991) mentioned that one of the reasons which made the Japanese model of economic development successful was that in that country, the agricultural output increased within the unchanged organisational framework of the existing on-farm resources of land and labour. The farmers have exploited the potential of technical innovations in terms of improvement in the productivity of the land and labour. In the process they obtained a flow of capital out of the agricultural sector to boost the industrial development. The lesson that the Japanese model gave was that the policy makers should design programmes to facilitate full exploitation of the technology by the farmers. Kalirajan (1991) in his study on adoption of rice technology in Coimbatore, India, reiterated that proper adoption of technology is as

important as the selection of technology to enhance the agricultural output. He found that the technical efficiency differentials did not disappear even after two decades of adoption of technology.

Agricultural production system is characterised by any one of the four basic resources technology situations viz., unlimited land static technology, limited land static technology, unlimited land dynamic technology and limited land dynamic technology. The last situation, where land is a scarce factor of production so that the growth of output depends on the intensive use of land with optimal mix of other inputs, is the one that involves the great majority of farmers in India. They are faced with the two constraints of inelastic supply of land and labour scarcity. They can overcome the first constraint by appropriate biological technology and the other through developing mechanical technology. While a few farmers fully exploit the potential of existing production technology, for many others farm yields are far below the potential level. Such productivity differentials reflect differences in the production conditions in any season and over time. Production conditions vary within each environment owing to micro physical and macro climatic factors.

The research in efficiency measurement was propelled by a pioneering paper which Farrell presented in the Royal Statistical Society 1957. He was the first to introduce and design the idea of efficiencies

that became the foundation for subsequent research in this area. He decried the futility of continuing to use the naive concept of productivity of labour and land to measure efficiency. He coined the term technical efficiency to refer to the ability of producing a given level of output with a minimum quantity of input, given the technology. Allocative efficiency referred to the choice of optimal input proportion, given relative prices. Economic or total efficiency is the product of technical and allocative efficiency. Subsequently, several extensions and refinements were made in the measurement of efficiency.

Studies on efficiency measurement are important because efficiency constitutes the first step in the process of resource saving. These resource savings have important implications for farm management as well as policy formulation. Efficient farmers are more likely to generate higher income and thus, stand a better chance of surviving and prospering (Bravo Urcta 1991).

In India, several researchers have applied efficiency measures as suggested in the literature and tried to measure the efficiency of the Indian farmers (Yotopoulos and Lau, 1971; Sampath, 1979; Kalirajan, 1982; Subramanian and Nirmala, 1988; Prasad, 1991). Kalirajan (1986) found that non-farm income and methods of crop establishment affected the technical efficiency at the farm level. Subramanian and Nirmala (1988)

who studied the farmers producing cotton in Madurai district, Tamilnadu, India, however, found that larger farms were relatively economically more efficient than small farms.

Hence the present study on “ASSESSMENT OF ECONOMIC EFFICIENCY: AN APPLICATION TO PADDY CULTIVATION IN TAMIL NADU” was undertaken:

- \* to study the existing input use behaviour by the farmer,
- \* to study the level of technical efficiency, allocative and economic efficiency through frontier models and
- \* to suggest policy options to improve the farming efficiency of farmers and to increase food production.

The measurement of efficiency was the main theme in the current study. The major objective was to evaluate the production efficiency of farms. For this analysis the production function was chosen because it would show the productivity of resources and returns to scale. When the production function is estimated using ordinary least squares (OLS) and evaluated at the mean level, it gives only average production and not the maximum. Hence, this was supplemented by estimation of Stochastic Frontier Production Function through COLS (Corrected Ordinary Least Square) and MLE (Maximum likelihood Estimation), PFPF (Probabilistic Frontier Production Function). Profit Function and Factor Demand Functions were also used as operational models to measure and compare economic efficiency and its components of technical and allocative efficiencies for sample farms.

To statistically test the above objectives the following hypotheses were formulated :

- \*Different farms employed different quantities of inputs resulting in different levels of output.
- \*When farmers used identical technology and the same amount of inputs with identical factor costs and identical expectation of present and future factor and commodity prices, there would be no difference in input and output levels among them.
- \*There exist differences in the levels of economic efficiencies achieved by different farms.

The study was carried out on a sample of 130 farmers spread over in the districts of erstwhile Periyar (Canal Irrigated Area) and Chengai MGR (Tank Irrigated Area) in Tamilnadu, using the farm records collected and maintained by the Tamilnadu Agricultural University under the Scheme of Cost of Cultivation on Principal Crops(CCPC) for the year 1993-'94. This study focused on the concept of whole farm production with a view to finding out the intensity with which the farmers used their land and other resources for maximising their farm incomes.

The concepts of economic and technical efficiencies are fundamental to agricultural policy making. The analysis of efficiency will help to know the possibilities for increasing output while conserving resource use. The role of increased efficiency will be viewed

as a vital complement to any set of policies to stimulate production and / or to promote resource conservation. This analysis is expected to help in understanding the efficiency of farmers and the agricultural system and the contributing factors to efficiency. It will also enable the farmers to formulate appropriate strategies to increase the farming efficiency under different scenario.

The study was confined to two areas *viz.*, canal irrigated and tank irrigated with specific agro-climatic conditions. Hence the conclusions will apply only to areas with similar conditions. In this study the price of inputs and outputs, production technologies and market conditions were taken as given and assessment of efficiencies was subject to rigorous statistical analysis only. However, this limitation will not affect the utility of the study because this model is amenable for extensive sensitivity analysis for likely changes in any of the above variables.

Efficiency studies done in location specific settings provide information about the extent to which the farmers in the region have absorbed the technology and drawn benefits out of it. When such studies are replicated in large numbers, they are useful for the policy planners to formulate their decisions on intervention strategy in extension and other supporting activities.

# Review of Literature

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## ***II. REVIEW OF LITERATURE***

The literature on economic efficiency in agriculture is reviewed and discussed under the following sections:

- A. Importance of efficiency studies in agriculture
- B. Concept of efficiency and measurement
- C. Methods/Models of measurement of efficiency
- D. Review of select studies

### ***A. Importance Of Efficiency Studies In Agriculture***

Productivity of labour was considered as a criterion to measure agricultural efficiency till Farrell (1957). This is unsatisfactory as it ignores all other input behaviour. Hence, Farrell estimated efficiency through frontier that takes into account all inputs.

The relative efficiency of farms in developing countries has been a topic of considerable interest in development literature. Often what is meant by efficiency is not clearly stated and an attempt at its measurement has made use of output-input ratios, particularly in labour productivity, without any basis in theory. Hence, from a theoretical point of view there has been a spirited debate on the relative importance of various components of farm efficiency. From an applied

perspective research measuring efficiency is important because it serves as the first step in the process leading to substantial savings in the use of resources. The resource savings have important implications for both policy formulation and farm management.

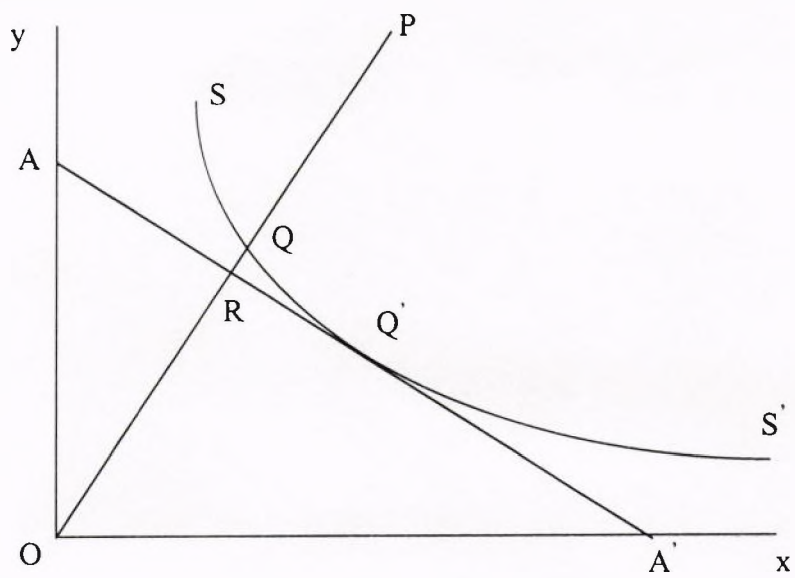
Economics is in many ways a science of efficiency, declares Sampath(1979). The policy implications of economic efficiency permeate both the micro and macro economic level. By means of efficiency the expected increase in output through appropriate re-organisation without absorbing additional resources in aggregate could be determined. Hence, policy recommendations in connection with land ceiling, land redistribution and land grouping under co-operative farming and other forms of agrarian organisation could be possible based on the mean level of efficiency.

A firm is said to be technically more efficient than other firms if it consistently produces larger quantities of output from the same measurable inputs. Differences in technical efficiency among groups of firms can be captured by quantifying their differences in technology. On the other hand, a firm is said to be price efficient if it maximises profits, since profit maximisation implies equalisation of the values of the marginal product of each variable input to its price. Yotopoulos and

Lawrence (1973) compared small and larger farmer's technical efficiency and concluded that small farmers are more efficient. They concluded that in agriculture direct supervisory and leadership role of the owner manager is apparently crucial for attaining higher level economic efficiency.

**B. *Concept of Efficiency and Measurement***

Farrell(1957) emphasised that productivity as a criterion of efficiency must be abandoned. He underlined the need for developing an alternate method to measure the efficiency of a firm. In his seminal paper on the measurement of productive efficiency, he had evolved a set of efficiency measures using the isoquants figure and had also developed a method to estimate the efficient production function applying it to American agriculture data by way of illustration. Farrell's contribution had formed the foundation for almost all empirical studies since then. In the process of elaborating his methodology, researchers had added substantially to the tool kit for measuring efficiencies in varied dimensions and situations. Hence, it is instructive to start from Farrell and then survey the developments brought about since then. The isoquant figure drawn on the assumption of constant returns to scale on the ground that the efficient production function is known, forms the basis for clarifying the concept of efficiency. Farrell started with a firm employing two factors of production to produce a single product as shown in the Figure 1.



*ISOQUANT*

In Figure, P represents the input of two factors per unit of output that the firm is observed to use. Isoquant  $SS'$ , represents various combinations of two factors that a perfectly efficient firm might use to produce unit output. Point Q, represents an efficient firm using the two factors in the same ratio as P, which produces the same amount of output as P, using only a fraction of  $OQ/OP$  as much of each factor. It could also be thought of as producing  $OP/OQ$  times as much output from the same inputs. Hence, Farrell defined  $OQ/OP$  as the technical efficiency (TE) of the firm P, however, to arrive at a measure of the extent to which the firm uses the various factors of production, in the best proportion in view of the prices, he considered  $AA'$ , (price line) which has a slope equal to the ratio of prices of two factors.  $Q'$  and not Q is the optimal method of production for, although both points represent 100 percent technical efficiencies, cost of production at  $Q'$  will be only a fraction  $OR/OQ$  of those at Q. This ratio was defined as price efficiency of firm Q. Further, if the observed firm were perfectly efficient both technically and in respect of prices, its costs would be a fraction  $OR/OP$

of what they are. In effect it is equal to the product of technical efficiency and production efficiency ( $OQ/OP \cdot OR/OQ = OR/OP$ ).

Between technical efficiency and price efficiency, Farrell considered the technical efficiency to be more important because of the following reasons:

1. The firm may be confronted not with perfect elastic supply of a factor but positive elasticity of supply which implies that the prices of those factors which are used more become dearer as the firm expands its production. It will imply that  $OR/OQ$  tend to under estimate the price efficiency of the firm,
2. The concept of price efficiency may not be necessarily desirable if the firm, as a matter of policy decides to operate above optimum output in a period of expansion or of temporarily high demand. In such cases, when the firm adjusts its inputs to a set of expected future prices, the concept of price efficiency based on static situation become irrelevant and
3. The concept of technical efficiency, on the other hand, has intrinsic usefulness since it indicates to the planners, the undisputed gain that can be achieved by simply gingering up the management.

Farrell (1957) thus evolved three specific measures of efficiency viz., technical, allocative and economic efficiencies on the assumption that the efficient production function is known.

Pitt and Lee (1981) and Ali and Chaudhry (1990) defined technical efficiency as the ability of a firm to achieve maximum possible output with available resources at a given technological level. Allocative efficiency is the ability to contrive an optimal allocation of given resources. Battese and Coelli (1988) defined it in terms of the ratio of the observed output to the corresponding frontier output conditioned on the levels of inputs used by that firm. According to Kalirajan (1990) and Kalirajan and Shand (1992), a firm was deemed to be technically efficient for a given technology, only if it realised its own technical efficiency potential and is producing on its outer boundary production frontier consistently in the socio-economic and physical environment. Allocative efficiency, that is its ability to maximise profit was measured by Kalirajan and Shand (1992) through equating firms specific marginal value product with firm specific marginal costs.

### **C. *Methods / Models for Measurement of Efficiencies***

Farrell (1957) chose the method of efficient production function to estimate a firm's technical efficiency related to the set of firms included in the function for which the function was estimated. His model presumed the existence of constant returns to scale with one

output and several inputs. He had demonstrated how his method of efficient production function depicted on the input-output space could be extended to cover multiple situations, single output and several inputs, multiple inputs and multiple outputs and quasi factors. He also suggested the Cobb Douglas function form since an estimated convex hull in the input space provided enough information to determine a production function in the constant returns to scale. Aigner and Chu (1968) were the first to follow Farrell's (1957) suggestion to specify a homogeneous Cobb Douglas production frontier with constant returns to scale.

Farrell and Fieldhouse (1962) applied the method developed by the former for estimating the efficient production functions in the context of increasing returns to scale that was essentially non convex.

Zellner *et al.*, (1966) considered two alternative specifications of the CobbDouglas production function model. The first one referred to the traditional model which assumed that firms operated on a non-stochastic production frontier function and maximised profits. The model, then, was made stochastic by the introduction of random

disturbance term. The second model assumed that the production functions of firms were identical in so far as firms and parameters were concerned and in addition were stochastic. In this model the profit function was random and it was assumed that firms maximised the mathematical expectation of profits. A distinction between the average and frontier function as predictors of capacity were made from the probability interpretation of alternative forecasts. The probability attached to output levels given by the average function were higher.

Aigner and Chu (1968) used the mathematical programming approach to estimate the production function of the firms. The empirical assumption for programming requires that disturbances are of one side, i.e., the observed points in the production surface lie on or below the frontier only. So long as measurement error is negligible, the author felt that the specification was justified. Applying the techniques of mathematical programming to cross section data on firms produces the envelope function by controlling the disturbance term to be on one side only.

Seitz (1970) estimated the frontier production function allowing for economies and diseconomies of scale using linear programming techniques. He specified three equivalent efficiency indices that

measured the efficiency of alternative scale activities. He also discussed the utility of efficiency indices in determining the nature of the production function, causes for the observed inefficiency and the degree and nature of technological advance.

Timmer (1971) used linear programming technique to estimate a Cobb Douglas production function frontier. He estimated the frontier input-output space in probabilistic fashion by constraining X percent of observations to fall outside the frontier surface. He investigated the alternative non deterministic specifications. The resulting model and the estimation techniques resembled those of Aigner and Chu (1968). The difference between the "best" practice and average practice was explained by the same set of factors that showed the difference in growth rates. He held that if all firms faced identical factor costs, the same technical production function and were allocatively efficient their relative average cost data would be sufficient to measure the relative technical efficiency.

Aigner *et al.*, (1977) suggested a new approach to the estimation of frontier production function. The earlier studies on frontier production function had not used an adequate characterization of the disturbance term. An appropriate specification was provided by these authors who defined the disturbance term as the sum of symmetric

normal and negative half normal random variables. Maximum likelihood estimation for the coefficients of a production function with an additional disturbance term of this sort was then considered.

Battese and Corra (1977) considered a statistical model for a production frontier which was consistent with the traditional (non stochastic) definition of a production function. Limiting cases of the model were the familiar average production model and envelope production function. Maximum likelihood estimates for the parameters were defined. Newton Raphson method was used to approximate the maximum likelihood estimates of the parameters in the production frontier, between observed output and the frontier. Schmidt *et al.*, (1980) discussed the models of deterministic parametric frontier, deterministic non parametric frontier, deterministic statistical frontier, stochastic frontier, duality considerations (considering the cost frontiers) and non frontier efficiency models. They concluded that in the deterministic and stochastic frontier models inefficiency was introduced by the disturbance term. In the non frontier model, inefficiency was introduced by varying coefficients or asymmetry.

Greene(1980) provided a simple estimator for the full frontier function that had all the properties of maximum likelihood estimators. The specification given in his study was a substantial modification of the

frontier estimators. He also estimated the production frontier model, using the trans-log functional model, since this model allowed for interaction between inputs. Additional information was obtained by estimating frontier in this framework. The use of a set of demand equations and a flexible functional form allowed the simultaneous estimation of both types of inefficiencies.

Stevenson (1980) developed a general stochastic model which did not need any assumption about the pattern of efficiency distribution throughout the sample. It also included special cases, zero and non zero modes for the distribution of efficiency levels among the economic agents.

Olson *et al.*, (1980) used the Monte-Carlo method to compare the small sample properties of various estimators of a stochastic frontier production function model of the type introduced by Aigner *et al* (1977) and Meeusen and Vanden Broeck (1977). The estimators considered were a corrected least square estimators (COLS), a two step Newton Raphson method and maximum likelihood estimators (MLE).

Schmidt and Lovell (1980) allowed for the possibility of positive correlation between technical and allocative inefficiency. Such a positive correlation was according to the intuitive supposition that poorly run firms will be poorly run both technically and

allocatively (operating far from their least cost expansion paths). They presented a model which allowed for correlation of inefficiencies which contained the Schmidt and Lovell (1990) model as the special case corresponding to zero correlation. It was found that technical and allocative efficiencies were correlated and this correlation caused estimated magnitudes and cost of both technical and allocative efficiencies to decline relative to an estimated stochastic frontier that remained essentially unaffected by generalisation.

Broeck *et al.*, (1980) estimated the stochastic frontier production functions by introducing a composed error structure in the production function to allow simultaneously, for system efficiency difference between production units and random difference. They compared the results obtained with this specification and technique developed by Aigner and Chu (1968) for estimated deterministic frontiers. The parameters estimated from the composed error model were more stable than the others.

Kopp and Diewert (1982) presented a method for decomposing the deviations from a full frontier cost function into Farrell measures of technical and allocative efficiencies. The method depends on duality theory and required no knowledge of the primal production frontier. This method is applicable to a broad class of cost functions including flexible

functions such as trans-log that do not possess analytically derivable properties underlying production functions.

Jondrow *et al.*, (1982) proposed a method of separating the error term into two components of  $u$  and  $v$  for each observation. This enabled the estimation of the level of technical inefficiency for each observation in the sample and largely removed the disadvantage of the stochastic frontier model relative to other models for which technical inefficiency was readily measured for each observation.

According to Bagi and Huang (1983) production frontier was primarily stochastic rather than deterministic. They used trans-log production instead of Cobb Douglas production function in order to allow interaction between inputs. Kalirajan and Flinn (1983) too had estimated measures of technical efficiency using a stochastic trans-log frontier.

Kalirajan (1986) developed a method to measure the firm specific technical efficiency for each observation in a sample by estimating a system of production frontier representing multiple outputs. This was applicable to more general cases of production in which the levels of outputs were interdependent. The advantage of this method was that a firm's technical efficiency in producing different individual products could be ranked from the system. Such a ranking

might indicate the firm's comparative advantage and direct optimal resource allocation.

Akridge(1986) demonstrated the limitations of employing a single product model in a multiple product situation. He used a frontier multi product cost function to measure productive efficiency. These conclusions were illustrated by Ekanayke and Jayasuriya (1987). The authors applied stochastic frontier production function analysis and COLS procedures to farm data from Sri Lanka. Their results indicated that the deterministic methods generally tend to overestimate the mean level of technical inefficiency and the extent of bias was not known. In contrast the stochastic frontier model enabled the separation of random noise from deviations arising from technical inefficiency.

Kumbhakar(1987) estimated technical and allocative inefficiency under behavioural assumption of profit maximisation. The estimates were derived in the context of Cobb Douglas production function. In a later study, he considered specification and estimation of technical and allocative inefficiencies in a cost minimising framework using panel data (Kumbhakar 1988). He introduced a flexible functional form of the production technology that permits elasticity of output to vary across firms and to introduce allocative efficiency separate from random errors in optimisation.

Battese and Coelli(1988) defined a stochastic frontier production function for panel data on sample firms. In their view the disturbances associated with a given firm involving the difference between traditional symmetric random errors and non negative firm effects are time invariant and have a general truncated normal distribution.

Ali and Chaudhry(1990) compared agricultural production efficiency in four integrated cropping regions of the Punjab Province of Pakistan. They estimated frontier production function for the whole farm survey data.

Bravo - Urceta and Rieger(1990) measured technical efficiency using four alternative production frontier models and evaluated the sensitivity of the results to the choice of the methodology. Their conclusions were: frontier function models were an upward scaled version of the OLS or average model and the different models yielded significantly different efficiency levels across farms. They also presented a stochastic efficiency decomposition model based on Kopp and Diewerts (1982) deterministic methodology.

Dawson *et al.*, (1991) calculated single measure of farm specific technical efficiency using the residuals of a stochastic frontier production function over time for rice farms in Central Luzon, the Philippines.

Bhavani(1991) attempted to investigate the efficiency of four digit level industries of metal produce group belonging to modern scale sector. She used trans-log production frontier to measure technical efficiencies of selected industries. She assessed the sensitivity of efficiency of estimate to the distribution used in the frontier model, namely Gamma, exponential and half normal.

### *Selection of Frontier*

The major objective of the present study is to evaluate the production efficiency of farms as mentioned in the previous section. For the above purpose production function is estimated by using OLS method which provides the average production and not the maximum production. To overcome this difficulty, the concept frontier by which maximum feasible yield may be estimated, is applied. Further the frontier is estimated by COLS (corrected ordinary least square) estimation method, MLE (maximum likelihood estimation) method and PFPF (probabilistic frontier production function). To measure and compare economic efficiency and its components, profit function and factor demand function are also employed.

The COLS eliminated the bias in the intercept term. The SFPF estimated by MLE considered the statistical distribution of one sided components, whereas PFPF takes care of outlier. The estimate of COLS,

SFPF and PFPF used for this analysis considered all possibilities of one-sided term.

**D. *Review of Select Studies***

Farrell(1957) enunciating the definition of various concepts of efficiency fitted a set of efficient production functions on the data of the American agriculture covering 48 states. He, however, observed that this was only an illustrative application and the results need to be replicated by using rigorous definitions of variables in individual settings.

Lau and Yotopoulos(1971) and Yotopoulos and Lawrence(1973) have proposed a model to measure separately the relative technical efficiency and price efficiency between farms and applied it to Indian agricultural data. In the formulation of test of equal relative economic efficiency, they used McFadden's profit function which expressed a farm's maximised profit as a function of prices of output and variable inputs of production and of the quantities of the fixed factors. They concluded that both small and large farms were price efficient moreover established the superior technical efficiency of small farms. The authors found the existence of constant returns to scale in Indian agriculture. Finally they advised that elaborate studies were needed to explain the so called unmeasurable factors which apparently caused the difference in technical efficiency of Indian farmers.

Battese and Corra(1977) had developed a statistical model for a production frontier that is consistent with the traditional non-stochastic definition of a production function given in micro economic theory. They have used Newton-Rhapson method to approximate the maximum likelihood estimate of the parameters of frontier production function. Applying this model they had estimated the production frontier for sheep production in the pastoral zone of Eastern Australia including the part of the three states, South Australia, New South Wales and Queen'sland. The data were obtained from the Bureau of Agricultural Economics for 1973-74 Australian Grazing Industry Survey. The value of sheep production was regressed against the cost of watering facilities, cost of fencing , cost of labour, cost of machinery inputs and cost associated with land. The variance ratio parameter used in maximum likelihood estimator is more than 95 percent for all regions and was significantly greater than zero indicating the good fit of the frontier function. The differences exist among the farmers was due to technical efficiency rather than random factors. The authors, however, have not worked out the estimates of technical or allocative efficiency components separately.

Forsund(1979) has studied technical and scale efficiencies parameters of Swedish milk processing industry during 1964-73. This included ten year data for 28 individual plants producing pasteurised milk.

The S1 measure is the relative reduction in the amount of inputs needed to produce the observed average industry output with frontier production technology, given the average factor proportion and size of plant indicated that the same output in the different years could have been produced by 57 to 70 percent of the observed amount used. The S2 measure is the ratio between the observed output and the output obtained for the observed amount of inputs by using frontier production technology with observed factors proportion revealed that the observed output ranges are 47 and 65 percent of potential output provided the inputs were employed in units with frontier production technology. For S3 the results showed that at the optimal scale on the frontier production function, the potential inputs coefficients are 47 to 65 percent of the observed input coefficients. The most remarkable result of the study was the rather large distance between best practice and average performances that deliberately showed an increasing trend during the period. These results were explained by rapid technical progress in combination with the putty-clay technological structure and slow growth in investment.

SamPATH(1979) tried to find out the nature and sources of economic inefficiency in terms of optimising models using linear programming technique. He observed that linear programming technique is the most suitable technique available for incorporating system rigidity and

imperfections in the form of constraints. He had evolved a modified approach to incorporate the sources of inefficiencies for the system rigidity or irrational decision making of the individual. The classification of economically inefficient situations tabulated by him numbered 16 in all. It helped in understanding the nature (technical, allocative efficiency or both) of economic inefficiency and its sources (the system, individual or both). Applying this methodology to the Farm Management Survey data of Deoria district in Uttar Pradesh in India, he had assessed the economic efficiency of farm size group-wise. He found the aggregate level of economic efficiency to be 63 percent. There was not much of a difference between small and large farms in the level of economic efficiencies achieved. Technical inefficiency contributed 65.1 percent. Thirty three percent was accounted for by allocative inefficiency and the rest by lack of mobility of factors of production. The sample confirmed to the 16th item in the classification developed by the author which meant that neither the system nor the individual was economically efficient in terms of both technical and allocative efficiencies. Within the group small farms were much more enterprising and innovative than larger farms in adopting the best technology, given their resource position.

Broeck *et al.*, (1980) had made a comparative study of estimates of deterministic and stochastic frontier production functions based on the

data of 28 individual plants producing pasteurised milk plants in Sweden during the period of 1964 - '73. They have applied linear programming method to estimate deterministic production frontier and maximum likelihood method for finding out the stochastic frontier. The comparison showed that the elasticity of labour tended to be similar both in maximum likelihood and linear programming results. The authors concluded from their studies that the smallest units were the least efficient in terms of distance from the efficient frontier. The efficiency frontier was also shifting gradually over time. The parameters estimated from the composed error model were more stable than other methods.

Kopp(1981) reported in his article on measurement of productivity efficiency: a re-consideration had generalised the Farrell Indexes of productive efficiencies to non-homothetic production technologies maintaining the cost interpretation of Farrell's measures. He had reviewed the developments in the estimation of several frontier costs and production functions, in his study of electric power generation. He extended it to regulated utilities where competitive pressure on efficiency is absent and objective function of the manager unclear. In his study he found that given the factor prices the technical efficiency of variable factors was 87 percent, allocative efficiency 99.5 percent and overall

productive efficiency approximately 86.5 percent. The fixity of capital was responsible for 4.5 percent increase in total cost.

Kalirajan(1982) had used two sets of variables for defining the factors influencing the technical efficiencies at the farm level, representing the farmer's technical knowledge and socio economic status and had estimated an equation by maximum likelihood method. It was found that non-farm income and method of crop establishment were the two major factors that affected the technical efficiencies at the farm level. Hence it was recommended that the extension service should disseminate the fine details of paddy production methods effectively and should also be reviewed periodically.

Kopp and Diewert(1982) had undertaken the frontier cost function estimation to derive measures of technical and allocative efficiencies. The authors pointed out that the estimation of primal frontier production function was subject to the problem of multi collinearity. The application of duality theory whereby the Stochastic frontier cost function is estimated and the underlying frontier production function is derived from the estimated cost function parameters, also restrict the production frontier specification which may be applied in this process. Many of the popular flexible functional forms, for e.g., the trans-log function do not possess this property . Hence the duality approach is not wholly

satisfactory. They presented an alternative which permit flexible functional farms and utilise only the information contained in the cost functions. Their method draws heavily on duality theory and requires no direct knowledge of production function specification or its parameters. By way of illustration they had taken up the data set of Capital, Labour, Energy and Machinery (KLEM) first introduced by Berndt and Wood(1978) and applied the trans-log frontier cost function method.

Dawson and Lingard(1984) measured farms specific Technical Efficiencies of rice farms in Central Luzon, Philippines using Stochastic Frontier Production Function approach. Their sample was drawn from International Rice Research Institute survey of 61, 57, 143 and 135 farms of Central Luzon in 1970, 74, 79 and 82 respectively.

In the production functions output was taken to be the physical amount of rice produced. The inputs consisted of four measurable inputs and two quantitative ones, area, fertiliser, labour, chemical mechanisation and irrigation. After Lingard *et al.*,(1987) the production technology of each farm is assumed to be characterised by a Cobb Douglas function. Apart from the usual rationale for its use, experience has shown that simple functions involving as few parameters as is practically feasible perform best, since convergence problems in the estimation process occur when there are a large number of independent

variables in the estimated equation. The Cobb Douglas functional form is a compromise between a complex production process and a complex estimation technique. They had used the Cobb Douglas Functional form to estimate the production frontier. The  $\gamma$  estimate varied between 0.96 to 0.99 over the period of study which indicated the most of the total variation of output in the frontier was attributed to technical inefficiencies. The short fall of realised output from the frontier is namely within the control of the individual farmers. Coefficients of skewness indicate that 1979 and 1982 are significantly negatively skewed, measures of kurtosis imply a mild but insignificant amount. Yet the authors concluded that a technical efficiency gap exist across the farmers that could be addressed specifically through policy intervention.

Kalirajan(1986) had evolved a method for estimating a system of Production Frontier representing multiple output which incidentally helps in ranking the firms by the comparative advantage and directing optimal resource allocation. Earlier the production frontier used for measuring firms specific technical efficiency was limited to single output. In this study the investigator had used a sample of 73 farmers of the province of Laguna in Philippines for the year 1979 who were growing sequentially three crops, rice-I, corn and rice-II. In transcendental logarithmic stochastic frontier, The three crops were regressed against

number of man days, area operated, quantity of fertilisers applied and other expenditures. The mean technical efficiencies worked out to be 0.60, 0.71 and 0.62 respectively for rice-I, corn and rice-II. Farmers on an average were producing corn more efficiently relatively to rice-I and rice-II. However, there were wide variations in the levels of technical efficiencies across sample farms. In the case of rice-I technical efficiencies ranged from 0.50- to 0.9. In corn it varied between 0.55 to 0.92 and in rice-II It varied 0.53 to 0.90. About 46 percent of sample participants were technically efficient in producing all the three crops. The others were in need of an improvement in their technical efficiency.

Akridge(1986) used the dual approach to measure productive efficiency in the multi product fertiliser plants. He maintained that examining the farms utilisation of individual inputs yield additional information on farm's efficiency. Since his study focused on shortrun cost minimisation problems he had used total variable cost while defining the technical, allocative and overall productive efficiencies. Technical Efficiency was defined as the ratio of technical efficient cost to observe cost. Allocative efficiency was the ratio of frontier cost to technical efficient cost. Overall technical efficiency was the ratio of the frontier cost to observed cost. Following Kopp and Diewert (1982) he estimated the technical efficient cost by the equation  $C^t(Y, W, K) = W^i X^t$ . He

pointed out that the generalised Farrell efficiencies measured the firms ability to employ effectively the full input vector and carried at direct cost interpretation. For example, the firm with 0.85 measure for overall productive efficiency could lower cost by 15 percent ( $(1.0 - OPE) \times 100$ ) by attaining both technical and allocative efficiencies. He had used data for 24 fertiliser plants in India over 1975-80. Using the maximum likelihood the frontier trans-log variable cost function was estimated along with two input cost share equations. He found that all frontier residuals were positive and none of the plants was directly on the frontier. The minimum, maximum and mean residuals for the average cost function indicated a fairly symmetric distribution. However, the mean frontier residual was 0.112 with a minimum of 0.008 and maximum of 0.349 suggesting skewed distribution of frontier residuals and providing additional support for the choice of maximum likelihood estimator procedure. The average overall productive efficiency of the sample was 0.90 implying that the firms in the sample could be reduced the total variable cost by 10 percent, if input use were reduced to technical and allocative efficient levels, because allocative efficiency was nearly unity for all plants in every year, virtually all the inefficiency was due to excessive input application, given the level and mix of output produced by the sample plants. The index of overall productive efficiency provided

a new source of information to the management on one specific area namely, variable cost control.

Ekanayake and Jaya Suriya(1987) had measured the firm specific technical efficiencies of rice farms in Sri Lanka in Mahawalli development project in the head and tail end areas in 1984 -85 crop year. The authors had used Stochastic Frontier Model with a composed weather structure because their frontier is depending by the entire sample and not limited to extreme observations as in the linear programming method. For comparison they had also used corrected ordinary least square method. They fitted Cobb Douglas Production frontier (Deterministic and Stochastic separately) for head and tail regions and a random sample of 63 and 61 farms respectively. The Stochastic frontier approach suggested that head reach region has variation in the output in the frontier were due to purely random factors. The ratio  $\gamma$  was not statistically significant. However, COLS measures showed substantial technical inefficiency in the head region and mean sample technical efficiency was 53 percent. Their dependent variable was rice and (unhusked) output in bush shell. The explanatory variable being used area cultivated in acres, number of mandays of labour in pre-harvest operation and quantity of nitrogen applied (in kg).

In the tail end region both procedures suggested the existence of considerable inefficiency and gave sample mean of technical efficiency 50 percent with Stochastic Frontier Model. The ratio  $\gamma$  was 0.97 statistically significant at 1.00 percent level implying that 97 percent of total variation of the output from the frontier was attributed to technical inefficiency. The authors mentioned that the high level of technical inefficiency in the tail region was not surprising because the available new rice production technology was developed for areas with adequate and timely supply of water. While these conditions prevailed in the head of the irrigation channel, the tail end region experienced severe problem with water. These uncertainties about water availability required farmers to exercise considerable skills in their management decision regarding timing and methods of various cultural practices. The farmers who were capable of adopting the available technology to their particular conditions obtained higher output in the head region. The complete absence of variation in technical efficiency among the farmers were explained by the existence of ideal environment for the practice of available technology in the recommended farm and which did not impose great demands on management skill. In a situation random variations were more important in explaining observed productivity differences between farms and differences between technical efficiency. In regard to the methods the

authors concluded the Stochastic Frontier Model enabled the separation of random noise from deviation arrived from technical inefficiencies. Hence, they recommended Stochastic Frontier Model as against others.

Lingard(1987) farm specific dummies are included to take into account the input of management with its essentially and observed output. These variables may include farmer's age, credit access, type of soil and so on. There is a danger that what is referred to as a management effect will include farm effect, i.e., effect of factors which do not depend upon management rather on the particular environmental conditions of the farms such as climate, soil type and topography. This would not affect the slope estimate or their properties but will change the meaning of the constant. It will now be an estimate of management and farm effect combined. A technical efficiency gap still exists across the sample and there is scope to narrow this by identifying the less efficient farms and further investigating the reasons for their relatively poor performances. A mix of physical factors and managerial attitudes will be responsible for constraining technical efficiencies on many farms. Appropriate policy programmes targeted at a less efficiency farm should enable the gap to be narrowed.

Subramanian and Nirmala(1988) studied the economic efficiency of large farmer group producing MCU-5 and LRA-5166

varieties of cotton in Madurai district using Lau-Yotopoulos profit function along with the four input demand equations. The study revealed that large farmers were relatively economically more efficient than the small farmers in the study area. The difference in economic efficiency between small and large farmers was attributed to difference in both price and technical efficiencies.

Kalirajan(1990) in his article on measuring economic efficiency considers a system consisting of a production frontier and factor share equations to measure firm's specific technical and input specific allocative efficiencies simultaneously. In estimating the system as a whole he used the joint distribution of all the errors in the equation and observes that this is more efficient than using the marginal distribution of the functions of the error as normally done by estimating either the profit function or production function alone. He illustrates the application of this method through a study of sample of 103 randomly drawn commercialized rice farms in Laguna Province, Phillipines. He had estimated the Stochastic Production Frontier and marginal productivity equation simultaneously for this sample. He found that the mean technical efficiency to be 0.7894 that implied that production on average was about 21 percent below the frontier. A considerable amount of production on an average was forgone due to technical inefficiency. The individual

technical efficiencies for the sample farms varied widely ranging from 0.6418 - 0.8206 .

Ali and Chaudhry(1990) had examined the inter-regional differentials in farm efficiency in Punjab Province of Pakistan using a deterministic frontier production function for the year 1984-'85 from the farm management's survey data available for 226 farmers in the districts of Gujranwala, Faisalabad, Sahiwal and Multan. The dependent variable in this model was the output of all crops. Fertiliser, irrigation, labour and farm power; land rent, farmyard manure were the explanatory variables.

Their results showed that technical efficiency in the rice , sugarcane mixed crop and cotton region ranged between 0.80 to 0.87. There was 13 to 20 percent potential to raise the gross income of the farmers at the existing level of farmers resources and technology which would increase the profit by upto 50 per cent in the production . The gap between the average and the best practice farmers was narrowed. Hence, they recommended strengthening of the existing extension service and organising pilot production programme to acquaint the less informed farmers with improved farming operations.

Allocative inefficiency was found highest in the cotton region and lowest in rice region. In cotton new technologies were evolved at a faster rate than in rice which dependent relatively on traditional technologies.

The variation in allocative inefficiency possibly reflected the differences in pace of adjustment. Unlike other studies on frontier production which were considered and confined to the specific crops, this study emphasised on the farms specific efficiency rather than crop specific efficiency.

Weersink et al.,(1990) had estimated the various measures of technical efficiencies using farm level data from Ontario Dairy Farm Accounting project wherein comprehensive data on 130 farms collected for each year replacing one-third of the farms every year. The data base used in the study related to the year 1987. Farms receiving more than 70 percent of the resources from milk production numbering 105 were included in the study of milk output in hecto litres were the dependent variable with livestock. Feed, machinery, building capital and other expenditure all measured in dollar terms and labour measured in worker equivalents were the explanatory variable. They have used linear programming models to derive efficiency at each farm by comparing its observed use of input and produced output related to all other farms. The results showed that the overall measure of technical efficiency ranged from 64.7 to 100 percent with 43 percent of sample exhibiting full efficiency. The mean efficiency value was 91.8 percent showing that the sample farms were operating at a high level of technical efficiency.

Congestion was also observed only on three farms. The dummy variables relating to the business organisation indicated that sole proprietorship and partnership were more efficient than corporate. On the whole the dairy sample farms were technically efficient the major source of inefficiency for the few remaining farms were due to pure technical allocation and non-optimal scale of production.

Kalirajan(1991) in his study on importance of efficient use in adoption technology had chosen the data of the paddy cultivation in Coimbatore, Tamilnadu, for the year 1983-86. In his study, efficient use of technology is defined as the ability to obtain the maximum possible output for the given quantity of conventional inputs and technology regardless of market demand, otherwise called technical efficiency. This way of defining technical efficiency means that the farms each have their unique potential production frontiers for a given technology and frontier may differ from one another based on the differences in their socio-economic and physical environment. The flexible trans-log function forms used in the study had output of rice in tonnes as dependent variable and independent variable. X1 denotes number of pre-harvest of labour used, X2 refers to amount of working capital which includes expenditure on fertilisers, pesticides, animal and machine power. X3 denotes rice area in hectares multiplied by soil fertility index. In the MLE function all

parameters were statistically significant at 5 percent level except the seasonal dummy and a seasonal dummy one if it was Kharif season or otherwise. The parameter was also statistically significant implying that the variation of an individual output from his maximum possible frontier output cease mainly from his inefficient use of the technology or technical inefficiency rather than random variability. The mean technical efficiency calculated was 69.3 percent. The individual firms exhibited a wide variation in the levels of technical efficiency ranging from 0.53 to 0.95.

The study showed a significant positive relation between technical efficiency and access to extension services as found in other developing countries. Formal education did not show up significantly whereas technical efficiency was neutral to farm size, supporting the arguments of Hayami(1981) and Rutton(1977) in this regard. To sum up, the study apparently rejected the hypothesis that farms will exploit the technology fully even under the known constraints. Low risk and well endowed production environment, inspite of all these favourable conditions, there still exists inefficiency in the use of technology which implies that there is an urgent need for improving technology absorption at the micro level to increase agricultural production at macro level.

Eswara Prasad(1991) studied technical efficiency of subsidised credit under Integrated Rural Development Programme using the concept

of frontier production function in Ananthapur district and arid region of Central India. They had extended the concept of production frontier function, to study the efficiency of credit used among 200 families that availed of subsidised credit under IRDP. The investigators had modelled the income relationship of the beneficiaries by a Cobb Douglas production function where the dependent variable was gross household income and independent variables were total mandays employed per household, total production assets, total production expenditure and loan amount received under IRDP. The authors had used corrected ordinary least square method to compute the estimates. The comparison of the actual and the frontier level of resources, use of the most efficient and the least efficient beneficiaries indicated that there was a high level of inefficiency in credit use. The study in effect demonstrated more provisions of financial assistance and assets creation did not enhance the income of the rural poor; in turn contributing to high levels of default in repayment.

To sum up, in 60s the deterministic Cobb Douglas production function was used as underlying model in studies on efficiencies and linear programming approach was used for estimating the coefficients by Aigner and Chu(1968), Farrell and Field house(1962) Zellner (1966), Seitz (1970) and Timmer(1971) among them Zellner and Timmer had used the probabilistic / Stochastic frontier production function approach.

In 70s, by and large stochastic frontier production model was applied and maximum likelihood estimator was used for estimating efficiencies by Aigner *et al* (1977), Battese and Corra (1977), Greene (1980), Olson (1980), Lovell (1980), Broeck *et.al.*,(1980), Kalirajan (1983), Kalirajan and Flin (1980), Ekanayake and Jayasurya (1987), Battese (1988), Ali and Chaudhry(1990), Bravo Ureta Rieger(1980) and Dawson *et al* (1991). They found unlike the deterministic frontier model which tends to over estimate the coefficients, the results of stochastic frontier production function model was more stable. This model enabled the decomposition of error term into two components  $u$  and  $v$ .  $u$  allowing systemic efficiency between firms and  $v$  summing up the random differences due to external factors. Kopp and Diewert (1982), Jondrow (1982), Kalirajan (1986), Bravo Ureta Rieger (1990) suggested methods for separating the error term into two components  $u$  and  $v$ .

Kopp(1981) and Kumbhakar(1987) had applied the duality theory and used cost minimisation trans-log function which could be applied to any underlying production function regardless of its constraints. Translog function has been preferred by Bagi (1982), since it allowed for interaction between inputs.

To sum up, the conceptual definition of efficiency did not undergo any change ever since Farrell defined it in 1957. The debate in the

literature was about the choice of appropriate underlying production function and its statistical properties. Cobb Douglas production function was the preferred form of the production function in view of its simplicity and ease in its computation. Between the deterministic production possibility frontier and stochastic production frontier, the latter was preferred in almost all the studies because the decomposition of error term enabled the estimation of the technical efficiency directly. The price and economic efficiency measure required some more calculation, namely estimation of normalised profit function and variable factor demand equation. Maximum likelihood estimation procedure was widely used in stochastic frontier production function. With the emergence of the duality theory it is now possible to free the production frontier from constraints of production function and one can go on to estimate trans-log function form in the cost minimising frame work.

In the present study technical efficiency is defined as the ability and willingness of the farmers to obtain the maximum output at a given level of inputs and technology. Allocative efficiency is defined as the ability to obtain the maximum profits from the application of inputs with a given set of farm specific input and output prices and a given technology. Economic efficiency is the product of technical and allocative

efficiencies. A farmer who is both technically and allocatively efficient is also economically efficient.

# Methodology

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### ***III. METHODOLOGY***

The methodology adopted for the current study on assessment of economic efficiency in the context of agriculture is presented and discussed under the following sections:

- A. Locale of the Study
- B. Sampling Design and Sources of Data
- C. Definition of variables used in the study
- D. Models of production function and other functions used
- E. Empirical Specification of the models used

#### ***A. Locale of the Study***

Tamilnadu is demarcated into eight homogeneous agro-climatic zones based on cropping pattern, soil types, rainfall and other factors. Agro-climatic factors such as soil, rainfall, temperature, humidity and physical and socio-economic and institutional factors. The interplay of all these factors defines the nature and characteristics of agricultural operation in a region.

The Periyar and Chengai MGR districts were drawn for the current study from two different agro-climatic zones, the former dominated by canal irrigation and latter by tank irrigation. These are used as canal irrigated area and tank irrigated area in the subsequent parts of the report to refer to the study areas (Please refer Figure - II and III).

**FIGURE - II**  
**PERIYAR DISTRICT - CANAL IRRIGATED AREA**

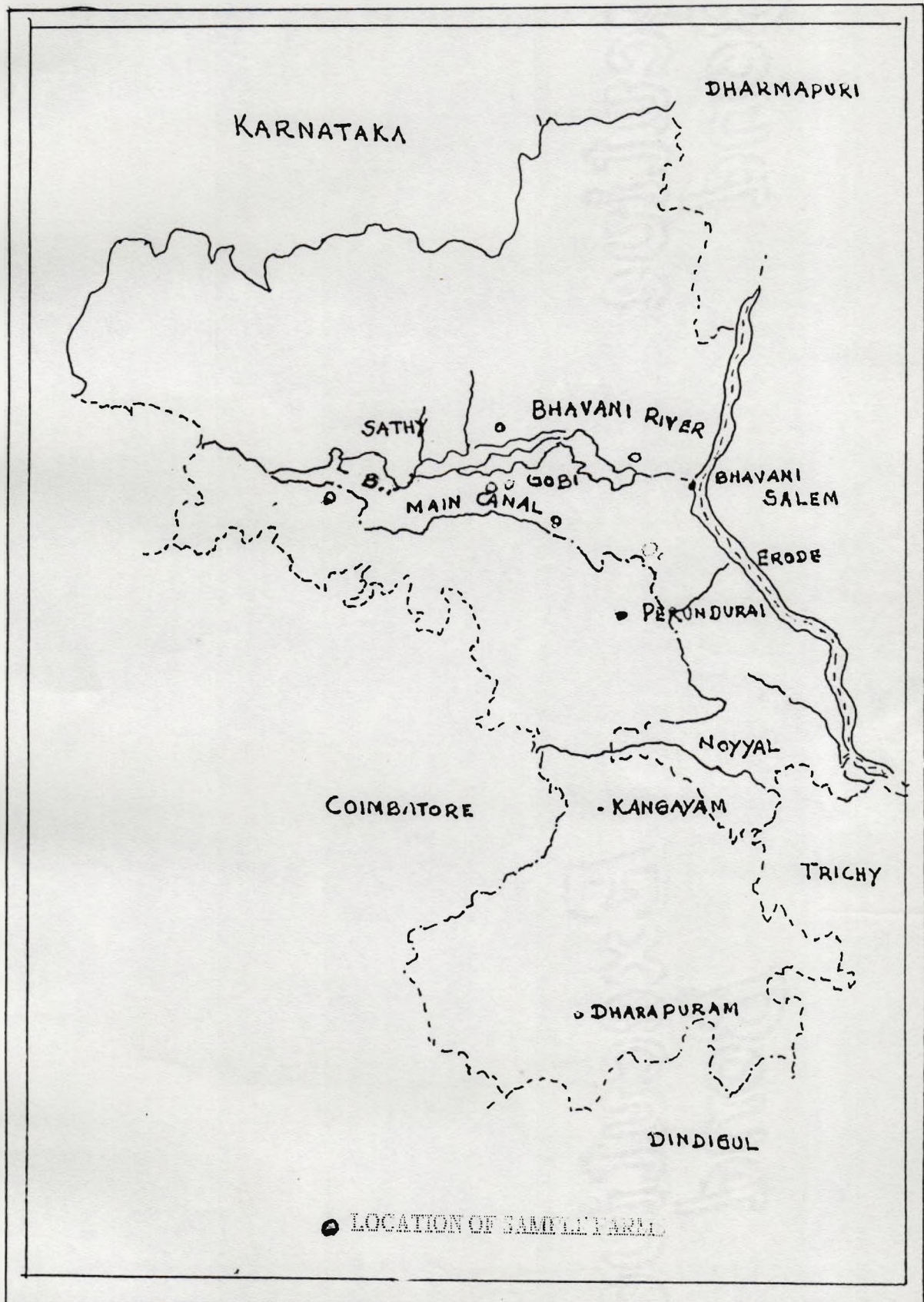
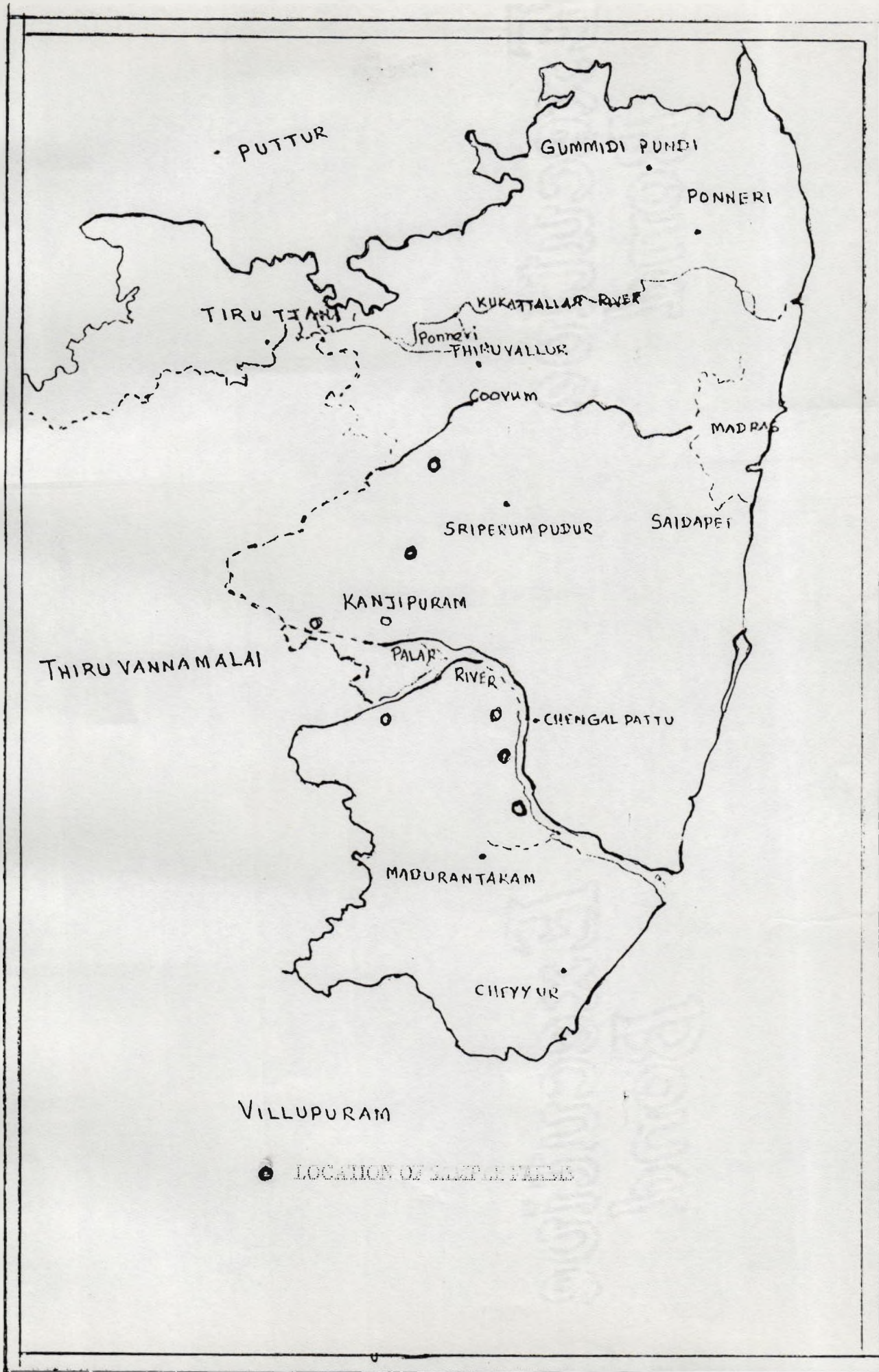


FIGURE - III  
CHENGAI MGR DISTRICT - TANK IRRIGATED AREA



## 1. Periyar District

The total population of Periyar district as per 1991 census was 23.21 lakhs. The rural population constitutes 17.47 lakhs and urban population around 5.74 lakhs. Canal and well irrigation system co-exists in this area. This district is land locked without any coastal line and has an area of 8829 sq km and lies between  $10.35^{\circ}$  and  $11.60^{\circ}$  of Northern latitude. It is located at around 171.91 metres above the mean sea level. The land area of the district is almost flat except some hills and rocks. There are three major rivers flowing through the district, the Cauvery and her tributaries namely Bhavani and Amaravathi. The first two are perennial rivers. Amaravathi river remains dry during summer.

This district has humid tropical climate. Its temperature normally reaches higher level between March and July and steadily drops with the setting of North-West monsoon. The district temperature in a year ranges between  $11.7^{\circ}\text{c}$  to  $41^{\circ}\text{c}$ . The relative humidity ranges between 40 per cent and 90 per cent. The normal rain fall in this district is 717.0 mm. This is far below the state normal rain fall of 942 mm. The North West monsoon accounts for a share of 44.11 percent followed by South West monsoon period which is about 30 per cent in the total rain fall.

The soil in the Periyar district is predominantly red-sandy to red-gravelly type in the taluks of Bhavani, Perundurai and Dharapuram. Red loamy soil occurs at the bottom of the valley in the taluks of Gobichettipalayam and Satyamangalam.

Out of the total cropped area of 3,61,863 hectares, 54 percent of the area is irrigated and 43 percent of the cultivated area is under food crops. Under food crops, paddy occupying 48 percent of the area. The other two major crops are sugarcane and cotton.

The farmers have grown paddy that accounted for a significant share of their farm income, the other crops are rather minor considering the value which they contribute to their whole farm income. Hence the whole farm income of the farmers was taken as a proxy for evaluating production function and related measures of efficiency.

## ***2.Chengai - MGR District***

The total population of Chengai-MGR district is 46.54 lakhs of which the rural population comprises of 25.55 lakhs and that of urban population around 20.99 lakhs (census 1991).

Chengai-MGR district is a coastal district situated on the North Eastern corner of Tamilnadu. It lies between  $12^{\circ}12'$  and  $80^{\circ}22'$  Eastern longitude. The total land area is 7920 sq km. It has a coastal line of 225 km. There are few hills of considerable elevation in this area. The chief rivers of the area are Palar, Korretaliar and Adayar.

Cooum, though not large, is a well-known river of the area. Kiliar and Kallar are the other rivers in the area and they are dry during major parts of the year.

The climate in this district is temperate. The average temperature ranges from 19.2 °c to 40.1° c. The hottest months are March to May. With the onset of South West monsoon, the temperature drops steadily. The rainfalls from the two monsoons are equal in this area. However, the North East monsoon brings a little higher rainfall during the third week of October. The annual rainfall of the area is 1165.3 mm and its share in South West and North East winter and hot weather seasons are 422 mm, 631 mm and 76.4 mm respectively.

Red non calcareous, moderately deep soil, alluvial soils, red calcareous soils and coastal alluvial soils are major soil types in this district. Of the above, red non calcareous soil forms 64 percent, black soil forms 15 percent, red calcareous soil forms 8 percent and sandy soil forms 13 percent which includes coastal sandy soil about 4 percent.

The total cultivated area in the district is 4,20,680 hectares of which 78 percent are irrigated. About 69 percent of the area is under food crops. Paddy cultivation occupies 63 percent of the area apart from other cereals and pulses; oil seeds are also cultivated in a large measure. Sugarcane and cotton constitute the two principal non-food crops.

Further details of the study area on population, rainfall, demographic features, soil, land utilisation, distribution of operational holdings, sources of irrigation, area under principal crops livestock and poultry population and input availability, are given in the Appendix (1)

#### **B. *Sampling Design and Source of Data***

The data used in the study were collected from the Scheme on Cost of Cultivation of Principal Crops (CCPC) operated in the Department of Agricultural Economics, Tamilnadu Agricultural University, Coimbatore. This scheme was initiated in 1971-'72 and is still being continued. The scheme generated the data through cost accounting approach, based on detailed records which report on every major aspect of the farm enterprise. The current study was based on the data collected for the agricultural year 1993-'94.

The scheme had used a three-stage stratified random sampling with taluks as the first stage units, cluster of villages as the second stage and farms as the third and ultimate stage unit. The primary sampling units (taluks) were allocated to different zones in proportion to the total area of the crops covered in the study. The primary sampling units were selected in each zone (Stratum) with probability proportioned to the area under selected crops and with replacement. Within each taluk the cluster of villages was also selected following the same procedure. Since the (CCPC) scheme covered 12 clusters in these two districts

with 130 farms of which 70 from Canal irrigated and 60 from tank irrigated areas were selected for the present study. All these farms had cultivated paddy. This principal crop was accounted for a significant share of their farm income. The other crops were insignificant considering the value that they contributed to the whole farm income.

### ***C. The Definition of Variables Used :***

The empirical analysis is done by quantifying the important input factors which are used in the current study.

#### ***Farm Income***

The gross output per farm is the aggregate value in rupees of physical output of the primary and secondary produce raised by the farmers valued at prices received by the farmers. The value of secondary produce reported by the farm was added to the value of the primary produce. The farms did not maintain any record of the production of livestock and it was not taken into account. The income from non-farm sources was excluded. For farms which did not sell a particular produce, the value of the produce was evaluated at the average price received by those who sold it.

#### ***Farm Size***

The size of the farm is measured as the operational area of the farm in hectares. This included the area owned plus the area leased-in minus

the area leased-out.

### ***Human Labour***

It is the number of days engaged in farm activities of both men and women and was expressed in man days of eight hours. The work units of different categories of labour were standardised on the basis of average wage that prevailed for male, female and juvenile labour in the study areas. Permanent labour, family labour, exchange labour and casual labour were treated alike for conversion purposes in terms of working hours. For contract labour it was carried out by assessing the normal requirement of labour for such operations.

### ***Pesticides***

Pesticides, herbicides and insecticides used in the crop production were evaluated at the local market prices that prevailed during the crop season.

### ***Fertiliser***

Manures and fertilisers were evaluated at the local market price that prevailed during the crop season irrespective of the fact whether they were farm produced or purchased. Manures include farm yard manure, compost and green manure.

### ***Material Cost***

Material cost was a comprehensive measure of all the cost of the inputs used. The seeds, manures, fertilisers, pesticides, herbicides,

insecticides were evaluated at the local market prices that prevailed during the crop season.

### ***Animal and Machine Power***

Bullock power was measured in terms of eight hours of work by a pair of bullocks and operated by a person. While the man-power used in the operation was added to the human labour measured in man days, use of bullock power in all operations was summed up and expressed in pair days. The cost of bullock power was per day average maintenance cost of bullock. Tractor used for agricultural operations such as ploughing, preparatory tillage, transport of manures and threshing were measured in hours. In calculating the cost of tractor use per hour, the variable cost included the cost of fuel, lubricants and salary to drivers paid on hourly basis. The fixed cost included depreciation on tractor and accessories, interest on capital loan (if any), insurance, tax, cost of repair, maintenance and registration charges. The per hour cost was worked out dividing total annual cost by total hours used on farms and custom hiring for non agricultural operations.

### ***Cropping and Irrigation Intensities***

Cropping Intensity referred to the ratio of gross cropped area to the net area sown expressed in percentage. Irrigation Intensity referred to the ratio of gross irrigated area to the net irrigated area expressed in percentage.

### ***Crop Diversification Index***

Since cropping intensity index takes no account of the difference in the maturing period of crops grown by different farmers and hence of no difference between the farmers in their ability to further intensify cultivation. The crop diversification index was used and it was defined as follows:

Crop diversification index

$$\frac{\sum_{i=1}^n a_i d_i}{12A}$$

where  $d_i$  is the duration in months of the  $i^{\text{th}}$  crop occupying the area  $a_i$  and  $A$  is the operational area.

### ***D. Models of Production Function and Other Functions Used***

The major objective of the study was to evaluate the production efficiency of farms and to analyse the differences, if any, between farms in different areas with respect to production efficiency.

For this purpose, analysis of production function was the choice because it would show the productivity of resources and returns to scale. The text book definition of production function holds that it gives the maximum possible output level which can be produced from a given vector of inputs. When the production function is estimated using

ordinary least squares (OLS) and evaluated at the mean level, it would give only average production and not maximum production. To overcome this difficulty, the concept of frontier was applied.

The measurement of efficiency has been the motivation for the study. The distance by which actual production point (level) lies below the production frontier (implied by maximum production) is considered as the measure of production efficiency. The concept of efficiency involves the following three components.

1. Technical efficiency (TE) is the ratio of the actual production ( $y_{it}$ ) to the maximum possible production ( $\hat{y}_{it}$ ). This ratio is positive and is less than unity.
2. Allocative efficiency is obtained by equating the marginal rate of technical substitution (MRTS) or the ratio of the marginal productivities of resources in the frontier production to factor prices.
3. The product of technical and allocative efficiencies is the Economic efficiency which is a necessary but a not sufficient condition for production efficiency. It should also be scale efficient

Since frontier production function is useful to study each of these components in the overall production function, it was employed in the present study. Among the several specification of the production

functions the Cobb Douglas production function was chosen because it took into account the nature of complementarity and substitutability among the factors of production namely,

1. Complementary factors of production with fixed proportions
2. Complementary factors of production with variable proportion and
3. Full substitutability between factors of production.

In agriculture the possibility is that inputs are either of type (2) or (3) or both. Transcendental and Cobb Douglas production functions were applied of which transcendental function incorporated all the three stages of production while Cobb Douglas production function explains only the important second stage of production assuming perfect competition.

### ***1. Frontier Production Function***

The maximum feasible yield function is defined as one that corresponds to the best practice technique among the given farmers. The production function showing such maximum feasible yield may be estimated by means of frontier production function.

The frontier production is defined as follows.

$$Y = f(x) \cdot \exp(w) \quad \dots(1)$$

where  $Y$  is  $(n \times 1)$  vector of observable random variables that are output values

$X$  is  $(n \times k)$  non negative constant that are inputs

$\exp(w)$ , the error term.

Suppose that a farm production is observed at a point  $(x^0, y^0)$ , such a farm is said to be technically efficient if  $Y^0 = f(x^0)$  and inefficient if  $Y^0 < f(x^0)$ . The maximum feasible yield is defined as

$$Y^* = \max (Y_i, H_i)$$

where  $Y_i$  gives the actual production of the  $i^{\text{th}}$  farm.

$H_i$  is the state of the technology for the  $i^{\text{th}}$  farm.

This maximum feasible yield is feasible for all, but is realised by atleast some sample farmers. These farmers were taken to be the reference case to define maximum production. The production function is

$$\hat{Y}_i = f_i(X_{ij}, H_i)$$

where  $\hat{Y}_i$  is the expected yield per hectare

$x_{ij}$  per hectare level of inputs vector,

The difference between the two is a measure of inefficiency in the production which implied that there is still scope for those who have not realised maximum feasible yield to raise production with the given technology by narrowing the gap in technology adoption.

## ***2. Stochastic Frontier Production Function***

The Deterministic frontier production function ignores the very real possibility that a farm's performance may be affected by factors

entirely outside its control, as well as factors under its control. The former is the collective effect of exogenous shocks both favourable and unfavourable and the latter is due to inefficiency in use of technology. These two sources of error need to be separated to understand the real cause of inefficiency. This is the idea behind the stochastic frontier production function.

In the stochastic frontier model, the error term is composed of two parts, a symmetric component which permits random variation of the frontier across farms, comprises effects of statistical noise and random shocks outside the control of the farms and one-sided component which captures the effect of inefficiency relative to the stochastic frontier.

The stochastic frontier model is as follows :

$$Y = f(x) \cdot \exp(w)$$

$$Y = f(x) \exp(-u + v)$$

$$Y = f(x) \exp(v) \cdot \exp(-u) \quad \dots(2)$$

where the stochastic frontier is  $f(x) \cdot \exp(v)$ ,  $v$  has symmetric distribution to capture the random effects of measurement error and exogenous shocks which cause the placement of the deterministic kernel  $f(x)$  to vary across the farms. Technical inefficiency relative to the stochastic production frontier is then captured by one sided error component  $\exp(-u)$ ,  $u \geq 0$ . This condition ensures that all the observations lie beneath the stochastic production frontier.

The Cobb Douglas function defined as

$$Y_i = A \prod_{j=1}^n (X_{ij})^{\beta_j} \exp(w_i) \quad \dots(3)$$

On natural log transformation it becomes

$$Y_i = \beta_0 + \sum_{j=1}^n \beta_j \log X_{ij} + w_i$$

$$Y_i = \beta_0 + \sum_{j=1}^n \beta_j x_{ij} + w_i \quad \dots(4)$$

where lower case letters represent the log values of the corresponding variables in (3) and  $\beta_0 = \log A$ , dividing the disturbance term  $w_i$  only into two components, a stochastic disturbance  $v_i$  and one sided efficiency disturbance  $-u_i$  and a joint density function based on the error term could be arrived at:

$$w_i = -u_i + v_i \quad \text{for all } i \quad \dots(5)$$

The model with this error specification is called as stochastic frontier since the non-positive component of the disturbance represents the shortfall of actual output from the frontier, while the frontier contains normal component of disturbance and is therefore stochastic. This specification avoids serious statistical difficulties as discussed by Greene (1980) that are encountered in the estimation of full frontiers i.e., the presence of purely non-positive error term.

Direct estimate of the stochastic production frontier may be obtained either by corrected ordinary least squares (COLS) or maximum

likelihood estimation procedure (MLE) (Appendix- II).

Aigner *et al.*,(1977) and Mccusen and Vanden Broeck (1977), considered exponential and half-normal distribution for  $u$ . Both have a zero mode. Stevenson(1980) had shown that the half normal and exponential distributions can be generalised to truncated normal and Gamma distributions respectively. These generalisations can have non zero mode with zero mode being testable as a special case. Therefore  $u$  is assumed to be non-positive. So by taking truncated normal and normal distributions for  $u_i$  and  $v_i$  respectively it is obtained as .

$$f(u_i) = \begin{cases} \frac{1}{\sigma_u \sqrt{1/2\pi}} \exp\left(\frac{-u_i^2}{2\sigma_u^2}\right) & \text{if } u_i \leq 0 \\ 0 & \text{otherwise} \end{cases} \quad \dots(6)$$

and

$$f(v_i) = \frac{1}{\sigma_v \sqrt{1/2\pi}} \exp\left(\frac{-v_i^2}{2\sigma_v^2}\right) \text{ for all } v_i \quad \dots(7)$$

The likelihood function of  $Y$  is the product of density function of each  $Y_i$  that is equal to density function of  $(u_i + v_i)$ . By convolution formula the joint density function of  $(u_i + v_i)$  could be written as

$$f(u_i + v_i) = \frac{1}{\sqrt{\frac{(\sigma_u^2 + \sigma_v^2)}{2\pi}}} \exp\left[\frac{(-u_i + v_i)^2}{2(\sigma_u^2 + \sigma_v^2)}\right] \left[1 - \left\{F(u_i + v_i) \frac{\sigma_u}{\sigma_v}\right\}\right] \quad \dots(8)$$

where

1.  $F(\cdot)$  is the cumulative distribution function of the standard normal variable.
2.  $\sigma^2 = \sigma_u^2 + \sigma_v^2$
3.  $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$  where  $\gamma$  lies in the interval (0,1).
4.  $w_i = u_i + v_i = y_i - \sum x_{ij} \beta_j$

Therefore the density function defined in (8) becomes

$$f(y_i) = \frac{1}{\sigma \sqrt{\pi/2}} \exp\left(-\frac{w_i^2}{2\sigma^2}\right) \left[1 - F\left(\frac{w_i}{\sigma} \sqrt{\frac{\gamma}{1-\gamma}}\right)\right] \quad \dots(9)$$

The parameterisation  $\gamma$  in the density function of  $y_i$  differs from, the one used by ~~Argner and others~~ <sup>Kalirajan</sup>. The advantage of using  $\gamma$  is that it varies between 0 and 1 while  $\lambda$  varies between 0 to  $\infty$ . So the complete region range of the parameter from 0 to  $\infty$  need to be explored to find the frontier function. But with  $\gamma$  trails are limited between 0 and 1,  $\gamma$  is an indicator of relative variability of  $u_i$  and  $v_i$  and that differentiates the actual yield obtained from maximum feasible yield.

There are two interesting points about  $\gamma$

1. Where  $\sigma_v^2$  is tending to zero which implies that  $u_i$  is the predominant error in (3) and then  $\gamma = 1$ . This means that farms yield differed from maximum feasible yield mainly because it did not use the best practice technique.

2. When  $\sigma_u^2$  is tending to zero, which implied that the symmetric error  $v_i$  is the predominant error in (3) and then  $\gamma$  is tending to zero. This means that the farms yield differed from maximum feasible yield mainly because of either statistical errors or external factors not under control.

The likelihood function which is the probability density of obtaining the sample  $(y_1, y_2, \dots, y_n)$  is written as

$$l(y, \theta) = \prod_{i=1}^n \frac{1}{\sigma \sqrt{\pi/2}} \left[ \frac{1}{\sigma} \left\{ \frac{y_i - \sum \beta_j x_{ij}}{\sigma} \right\}^{\sqrt{\gamma/(1-\gamma)}} \right] \exp \left[ -\frac{1}{2} \frac{(y_i - \sum \beta_j x_{ij})^2}{\sigma^2} \right] \quad \dots(10)$$

where  $\theta$  is the parameter to be estimated which contains the elements  $\beta_0, \beta, \sigma^2$  and  $\gamma$ .

Since the natural logarithm of a function has the maximum point at the same position as the original function, taking logarithm of likelihood function L

$$\ln L = -\frac{n}{2} \ln \frac{\pi}{2} - \frac{n}{2} \ln \sigma^2 - \sum \ln[1 - F(Z_i)] - \frac{1-\gamma}{2\gamma} \sum Z_i^2 \quad \dots(11)$$

$$\text{where } Z_i^2 = (y_i - \sum \beta_j x_{ij}) \left[ \frac{\gamma}{(1-\gamma)\sigma^2} \right]^{\frac{1}{2}}$$

Maximising the above likelihood function the ML estimators  $\theta$  are obtained by setting its first order partial derivatives with respect to the element of  $\theta$  viz.  $\beta, \sigma^2, \gamma$  equal to zero and solving them simultaneously

(vide details in Appendix III.)

An alternative to this assumption (but within feasible range) of arbitrary values of ( $\gamma$ ) and consequent iterative procedure was suggested by Farrell(1957). It is a programming technique.

The Cobb Douglas function is written as

$$Y_i = \beta_0 + \sum_{j=1}^n \beta_j x_{ij} + w_i \quad \dots(12)$$

and more generally it is written as

$$Y_i = \sum_{j=0}^n \beta_j x_{ij} + w_i \quad \dots(13)$$

where  $x_{i0} = 1$  for all  $i$  Farrell used programming technique to estimate frontier production function as an envelope of observations in unit input-output space. His method possessed the serious limitations of not considering non-constant returns to scale and greater sensitivity to extreme observations which may arise due to errors in measurement. In fact, extreme observations were used to estimate the frontier.

To overcome these limitations inherent in Farrell's method, Aigner and Chu(1968) derived a method of estimating frontier production function by constraining the error to be non-positive.  $\beta_i$  could be estimated by minimising either the sum of residuals or squared residuals.

Assuming that the maximum feasible yield is given by

$$y^* = \sum_{j=0}^n \beta_j^* x_{ij} \quad \dots(14)$$

and each farm's output may be represented

$$y = \sum_{j=0}^n \beta_j^* x_{ij} + u_i, \quad u_i \leq 0 \quad \dots(15)$$

by convention that  $u_i \leq 0$ , the non positive error term is the difference between the yield obtained and the yield estimated by fitting the function to represent maximum feasible yield,  $u_i$  can be zero or negative. If  $u_i = 0$  the farms used the best practice technique and obtained maximum feasible yield. On the other hand  $u_i$  will be negative for farms not using the best practice technique and negative values vary among the farms depending on their technical efficiency according to how close they are to the best practice technique.

Even without specifying the probability on  $u_i$  a function showing maximum feasible yield may be estimated by linear or quadratic programming technique. The programming techniques minimised the sum of absolute differences or sum of squared differences with the constraint that the differences be either negative or zero. Timmer(1971) pointed that such programming techniques do not take into account of the statistical errors and provided a simple method to deal with these errors to some extent. He deleted certain percentage of observations assuming that they are affected by statistical errors and estimated the frontier production function using the remaining observations by

means of linear programming techniques. Thus he gave a probabilistic approach to the deterministic frontier used by Aigner and Chu (1968). The selection of these percentages of observations was not explained by either economic or statistical justification. A major drawback of the linear programming technique is that the estimated frontier is supported by a subset of data and is therefore extremely sensitive to the outliers.

### 3. *Probabilistic Frontier Production Function*

Aigner and Chu recommended the use of probabilistic Frontier production function to take care of the sensitivity problem arising from the inclusion of outlier in the linear programming.

$$y_i = \sum_{j=0}^n \beta_j x_{ij} + u_i$$

probability statement of the farms

$$P\left(\sum_{j=0}^n \beta_j x_{ij} > y_i\right) \geq P \quad i=1,2,3,\dots,n \quad \dots(16)$$

where P is the extremely specified probability within which alone statement holds. The approach consisted of estimating the frontier using all observations and re-estimating the frontier after discarding the first 100 percent efficient farms until the predetermined p is obtained. An alternative to this is to simply discard the efficient observations until the resulting coefficients stabilise (The details of estimation procedure are given in Appendix IV).

Given the technology, allocative efficiency referred to the achievement of optimum output so as to maximise profit. It is reasonable to assume that alternative methods of input application could have different effect on output. In particular a farm which used the best practice method achieved the maximum possible output, which is superior to a farm which does not do the same with given similar bundle of inputs and technology. A conventional production function is stated purely with the measurable inputs which cannot capture this. The stochastic frontier production function method popularised by Aigner et al (1968) could also be used to measure the effect of variations in the manner of application of inputs on outputs. The comprehensive discussion on the evaluation of frontier production function is given by Forsund et al. (1980). Next given the technology, farms are expected to make adjustment in the levels of application of inputs to achieve allocative efficiency.

For a given technology and endowment of fixed factors of production, the function expressed the maximised profit of a farm as a function of the quantity of fixed factors of production (Yotopoulos and Lau 1979). In the present study the profit function was used as an operational model to measure and compare economic efficiency and its components of technical efficiency and price or allocative efficiency for

sample farmers. The model is identical to the one used by Yotopoulos and Lau. (The estimation of profit function is given in Appendix IV).

The profit function is defined as

$$\ln \pi^* = \ln A^* + \sum_{i=1}^m \beta_i^* \ln \gamma_i + \sum_{i=m+1}^n \alpha_i^* \ln z_i \quad \dots(17)$$

where

$$A^* = A (1-w)^{-1} w_i \prod_{i=1}^m \beta_i \beta (1-w)^{-1}$$

$$\beta_i^* = -\beta_i (1-w)^{-1} < 0, \quad i = 1, 2, \dots, m$$

$$\alpha_i^* = \alpha_i (1-w)^{-1} > 0, \quad i = m+1, m+2, \dots, n$$

which has been suitably modified to identify the components of technical and price efficiencies. Considering the farms of the two areas (farms from canal irrigated area as 1 and farms of tank irrigated area as 2), the production function is written as

$$y^1 = A^1 f_1(x^1 z^1)$$

$$y^2 = A^2 f_2(x^2 z^2) \quad \dots(18)$$

with usual definition of  $y$ ,  $x$  and  $z$ . The farm specific technical efficiency was captured by the natural differences in the production function  $A^1$  and  $A^2$ . The groups of farmers are equally technically efficient if  $A^1 = A^2$ . Now the marginal condition for the two groups assuming that the farmers face different input prices i.e. given by

$$\frac{\partial y^1}{\partial x_j^1} = k_j^1 r_j^1$$

$$\frac{\partial y^2}{\partial x_j^2} = k_j^2 r_j^2 \quad \dots(19)$$

The above equations enabled to allow interfarm differences in their ability to equate the value of marginal product of the variable factors to their prices. In equation (19) .  $k_j^i$   $i=1,2$  represented the farm and the variable factors specific differences managerial entrepreneurial ability showing different degrees of equality, the marginal variable product and its price. The groups are equally price efficient regarding to all variable inputs if  $k_j^1 = k_j^2$ ,  $j=1,2,\dots,m$ . In the context of Cobb Douglas form of production function , the UOP related to its with technical and price efficiency parameters  $A^i$

$$\pi^i = A^i(1-w)^{-1} \left[ 1 - \sum_{j=1}^m \frac{\beta_j}{k_j^i} \right] \left[ \prod_{j=1}^m (k_j^i)^{-\beta_j(1-w)^{-1}} \right] \left[ \prod_{j=1}^m (\beta_j)^{\beta_j(1-w)^{-1}} \right] \quad (20)$$

$$\left[ \prod_{j=1}^m (r_j^i)^{-\beta_j(1-w)^{-1}} \right] \left[ \prod_{j=m+1}^n (z_j^i)^{-\alpha_j(1-w)^{-1}} \right] \quad \text{for } i = 1,2,\dots$$

$$\text{that is } \pi^i = A_*^i \left[ \prod_{j=1}^m (r_j^i)^{\beta_j^*} \right] \left[ \prod_{j=m+1}^n (z_j^i)^{\alpha_j^*} \right] \quad \text{for } i = 1,2,\dots$$

where

$$A_*^i = A^i(1-w)^{-1} \left[ 1 - \sum_{j=1}^m \frac{\beta_j}{k_j^i} \right] \left[ \prod_{j=1}^m (k_j^i)^{-\beta_j(1-w)^{-1}} \right] \left[ \prod_{j=1}^m (\beta_j)^{\beta_j(1-w)^{-1}} \right]$$

$$k_j^* \left[ 1 - \sum_{j=1}^m \frac{\beta_j}{k_j^i} \right] (1-w)^{-1} \quad j = 1, 2, \dots, m$$

$$\beta_j^* = -\beta_j (1-w)^{-1} < 0 \quad j = 1, 2, \dots, m$$

$$\alpha_j^* = \alpha_j (1-w)^{-1} > 0 \quad j = m+1, \dots, n$$

#### 4. The Factor Demand Function by Shepherd's Lemma

The Shepherd's Lemma enabled to derive factor demand function of variable inputs and the supply function from the (unit output price ) UOP profit function by differentiating the equation which expresses with output profit function in terms of variable normalised input prices and fixed factors of production can be solved for variable factor demand function and output supply function which are given respectively

$$\text{as } x_i^* = \frac{\partial g(\gamma, z)}{\partial \gamma_i} \quad i = 1, 2, \dots, m$$

and from the definition of normalised profit

$$\begin{aligned} T^* &= g(\gamma, z) - \sum_{i=1}^m \left[ \frac{\partial g(\gamma, z)}{\partial \gamma_i} \right] \gamma_i \\ X_j^i &= -\frac{A^i}{k_j} \frac{\partial g}{\partial \gamma_j^i} \left( \frac{k^i \gamma^i}{A^i z^i} \right) \quad i=1, 2 \quad \text{and } j = 1, 2, \dots, n \quad \dots(21) \end{aligned}$$

where  $g(\cdot)$  in the UOP profit function corresponding to the production (18). The variable factor demand functions are given by (21) and direct computation are written as

$$X_s^i = A^{i(1-w)^{-1}} \left[ \frac{\beta_s}{k_s^i} \right] \left[ \sum_{j=1}^m (k_j^i)^{-\beta(1-w)^{-1}} \right] \left[ \sum_{j=1}^m (\beta_j)^{\beta(1-w)^{-1}} \right] \left[ \sum_{j=1}^m (r^i_j)^{-\beta(1-w)^{-1}} \right] \left[ \sum_{j=m+1}^n (z^i_j)^{-r_j(1-w)^{-1}} \right] \quad i=1,2 \text{ and } s=1,2,\dots,m \quad (22)$$

$$X_s^i = A_s^i \beta_s^* (k_s^i)^{-1} (r_s^i)^{-1} (k_s^i)^{-1} \left[ \prod_{j=1}^m (r_j^i)^{\beta_j^*} \right] \left[ \prod_{j=m+1}^n (z_j^i)^{\alpha_j^*} \right] \quad \dots(23)$$

by substituting from (21)

$$X_s^i = \frac{r_s^i X_s^i}{\pi_i}$$

$$= (k_s^i) (k_s^i)^{-1} \beta_s^* = \beta_s^* \quad i=1,2$$

$$s=1,2,\dots,m$$

This implied that the elasticities of variable inputs estimated from the variable factor demand function (21) are equal to the respective elasticities estimated from profit function (20.)

### ***E. Empirical Specification of Models Used***

In the present study the specified functions may be estimated by means of the variable quantified to know the behaviour of the inputs and efficiency of the farms.

#### ***1. Unit Output Price Profit Function.***

For estimating the UOP profit function the equation used is as

$$\ln \pi = \lambda_0 + \alpha_0^* D_1 + \beta_1^* \ln w + \beta_2^* \ln F + \beta_3^* \ln B + \alpha_1^* \ln L \quad \dots(24)$$

where  $\pi$  = UOP Profit (in Rs.)

$w$  = Normalised wage for labour (in Rs.)

$F$  = Normalised fertiliser price (in Rs.)

$B$  = Normalised wage for bullock and machine power (in Rs.)

$L$  = Cultivated area (in hectares)

$\lambda = \ln A^*$

$D_1 = \begin{matrix} 1 \text{ for farms of canal irrigated area} \\ 0, \text{ otherwise} \end{matrix}$

## 2. Factor Demand Functions.

Factor demand functions are written as

$$\frac{-wX_1}{\pi} = \beta_1^{*p} D_1 + \beta^{*c} D_2$$

$$\frac{-FX_2}{\pi} = \beta_2^{*p} D_1 + \beta_2^{*c} D_2$$

$$\frac{-BX_3}{\pi} = \beta_3^{*p} D_1 + \beta_3^{*c} D_2$$

where  $x_1$  = Total labour (man days)

$x_2$  = Total Fertiliser and Pesticides used (Rupees).

$x_3$  = Total bullock and machine power used (Pair days)

$D_1 = \begin{matrix} 1 \text{ for farms in Canal irrigated area} \\ 0 \text{ otherwise} \end{matrix}$

$D_2 = \begin{matrix} 1 \text{ for farms in Tank irrigated area} \\ 0 \text{ otherwise} \end{matrix}$

The hypothesis to be tested about the economic efficiency with the profit function is that there is equal relative economic efficiency among farms in the study area. This requires that UOP profit functions

of the farms of both the area and the variable factors demand functions coincide with each other. This implies that

$$A^{*P} = A^{*C} \quad (\text{as in 21) and}$$

$$\beta_s^{*P} = \beta_s^{*C}$$

This equality will happen if  $A^{*1} = A^{*2}$  and  $K^1 = K^2$  in UOP profit functions (20). The relationships enabled to test for the two components of economic efficiency namely equal relative technical efficiency and price efficiency. This is equivalent to testing whether the coefficients of the dummy variable differentiating the two profit functions  $\alpha^*_0$  is zero in equation (22). It may be noted that it is possible for two farms to be equally efficient economically without being equally efficient technically or equally price efficient. A test for equal relative price efficiency between farms of two areas consisted of examining whether both farms in the study areas have the same price efficiency parameter  $K_s$ . This is equivalent to testing the hypothesis that the elasticities of variable inputs of both groups estimated from their factor demand functions are same.

$$\beta_s^{*P} = \beta_s^{*C}$$

A test for equal relative technical efficiency consisted of testing the joint hypothesis of economic and price efficiency as

$$EE = TE \times PE$$

$$\alpha^*_0 = 0, \beta_s^{*P} = \beta_s^{*C} \quad s = 1, 2, 3$$

Testing whether the elasticities of variable factors of production estimated from the factor demand functions of farms of the two areas are equal to the respective elasticities estimated from their profit functions that

$$\beta_s^* = \beta_s, \quad s = 1, 2, 3$$

It is equivalent to testing whether the farms maximising their profits perfectly. It is equivalent to absolute price efficiency of farms.

## Results and Discussion

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## *IV. Results and Discussion*

The results of the study on assessment of efficiency in paddy cultivation in Tamilnadu are presented and discussed under following sections:

- A. Profile of the sample farms
- B. Input use behaviour on sample farms
- C. Measures of efficiency in sample farms.

### *A. Profile of the Sample Farms*

The profile of the sample farmers in the study area is discussed in terms of their farm size, family size, educational status, cropping pattern, cropping and irrigation intensities and assets.

#### *1. Farm Size*

Farm size is an important parameter in any economic analysis. It was measured by the operational area of the farms which included owned land plus leased-in and minus leased-out, wet, garden and dry land area operated by the farmers. Area under non-agricultural use and permanent trees were excluded. Average size of the farms and its distribution are presented in Table I, for the farms of canal irrigated area and tank irrigated area.

**TABLE I**  
**MEAN FARM SIZE IN THE STUDY AREAS**

( in hectares )

<i>S.No.</i>	<i>Operational Holdings</i>	<i>Canal Irrigated Area</i>	<i>Tank Irrigated Area</i>
1	Owned Land	2.41 (81.60)	1.70 (77.76)
2	Leased in Land	0.91 (30.88)	0.80 (36.60)
3	Leased out Land	0.37 (12.48)	0.30 (14.36)
4	Total (1 + 2 - 3)	2.95 (100.00)	2.195 (100.00)
5	Standard Deviation	0.45	0.84
6	Variation between Farms (C.V.%)	15.23%	38.64%

Note :The figures in the parentheses indicate the percentage to the total.

The average operational area of farms of canal irrigated area. was 2.95 hectares and in tank irrigated area, it was 2.2 hectares. The variability in land holdings was higher in the tank irrigated area when compared to that of canal irrigated area. The proportion of leased in and leased out were relatively higher in tank irrigated area. The average size of the operational holding (farm size) was comparatively higher in farms of canal irrigated area. There was general aversion among these farmers to lease out their land. This explains the very low percentage of area leased out. To increase their farm income and to make use of family labour, owned bullock power and machine power farmers went in for leased in land. The small size of farms indicated the prevalence of poor resources of the farmers in two areas under study irrespective of the sources of irrigation.

## **2. *Family Size***

The mean size in sample farm households, together with its composition is given in Table II.

**TABLE. II**  
**MEAN FAMILY SIZE AND COMPOSITION OF**  
**HOUSEHOLDS IN THE STUDY AREAS**

<i>S.No.</i>	<i>Particulars</i>	<i>canal irrigated area</i>	<i>Tank irrigated area</i>
1	Male	1.96 (38.13)	2.70 (40.85)
2	Female	1.83 (35.60)	2.39 (36.15)
3	Children	1.35 (26.27)	1.52 (23.00)
4	Family Size	5.14 (100)	6.61 (100)
5	Earners	2.54 (49.42)	3.07 (43.00)

Note : The figures in the parentheses represent the percentage to the total.

Average family size worked out to 5 and 6 persons respectively, in canal irrigated and tank irrigated areas.

The dependency ratio in the farm household in canal and tank irrigated areas are 50 and 57 percent, respectively. The mean earners per family in this areas are 2.5 and 3.0. In general, greater the income opportunities in alternative occupations, the smaller the quantity of labour supplied to agriculture. In subsistence agricultural economies off-farm employment opportunities are scarce. Consequently, the opportunity cost of family labour might be presumed to be very small. In both the study areas, however, there was a fair degree of commercialisation of agriculture and both the regions had a good number of service and manufacturing firms. Hence, farm family labour had ample opportunities for off-farm and non-farm employment, To that extent the opportunity cost of alternative employment for family labour exceeded the returns to family labour from farm enterprises.

### ***3. Educational Status***

Analysis of educational status of the selected respondents was done to know the influence, if any, of education on the adoption of new technology in crop production. The literacy level of farm families would stimulate the quick adoption of technological advances in agriculture which in turn would influence efficiency of the farms (Table III). In addition table III gives the educational status of the sample farmers in the study areas.

**TABLE. III**  
**EDUCATIONAL STATUS OF THE HEADS OF FARM**  
**FAMILIES IN THE STUDY AREAS.**

<i>S.No.</i>	<i>Literacy Level of farm family heads</i>	<i>Canal irrigated area</i>	<i>Tank irrigated area</i>
1	Illiterate	5 (7.14)	4 (6.67)
2	Primary	5 (7.14)	10 (16.67)
3	Secondary	18 (25.72)	17 (28.33)
4	Higher Secondary	20 (28.57)	17 (28.33)
5	Collegiate	22 (31.00)	12 (20.00)

Note : The figures in the parentheses indicate the percentage to the column total.

The percentage of illiterates was low in both areas and it was a welcome sign to expect progressiveness in the outlook of the farmers. Forty three to 47 percent of farmers in both the areas had higher secondary and collegiate education. This revealed that the introduction of any new technology would be easy and farmers would accept any new innovation quickly.

#### **4. *Cropping Pattern***

A study of cropping pattern indicates the economic significance of different crops in the region. The cropping pattern of the farms of both the areas is presented in Table IV.

**TABLE. IV**  
**CROPPING PATTERN OF THE SAMPLE FARMS**  
**IN THE STUDY AREAS**

*( in hectares)*

<i>S.No.</i>	<i>Name of the Crop</i>	<i>Canal Irrigated Area</i>	<i>Tank Irrigated Area</i>
1	Paddy	183.17 (52.02)	89.40 (52.10)
2	Sugarcane	72.22 (20.51)	39.37 (22.94)
3	Banana	39.12 (11.11)	22.81 (13.30)
4	Groundnut	19.69 (5.59)	12.30 (7.17)
5	Coconut	30.86 (8.77)	4.64 (2.70)
6	Millets	7.04 (2.00)	3.08 (1.79)
7	Gross Cropped Area	352.10 (100)	171.60 (100)
8	Crop Diversification Index	1.18	0.91

Note : The figures are the sum of all farms taken together.  
The figures in the parantheses indicate the percentage to the total

The principal crop in the study areas was paddy, an extent of 52 percent of the cultivated areas. Sugarcane was the second major crop in both the region occupying 20 and 23 percent of the cultivated land in canal and tank irrigated areas. The other crops were banana, groundnut, coconut and millets. The relative share of these crops varied among the farms of the canal irrigated and tank irrigated areas. Thus, a large degree of commercialisation of farms was observed in both areas.

The factors influencing cropping pattern are grouped into two broad categories (i.e) economic and technical. The first group of factors include profitability as influenced by technology and relative prices, risk and uncertainty associated with crops, working capital requirement for individual crops, access to credit and interest on borrowed capital. The latter group include technical factors such as suitability of soil, time available between ploughing and planting, season specificity of individual crops and requirement of human labour. In a compact area as the one covered by this study, technical factors least differed between farms. Therefore, economic factors are important for explaining the differences in cropping pattern among the farms.

Crop diversification enabled the farmers to use land and water resources efficiently. The crops would use soil nutrients at various depths

and also in different seasons. Further, this is a strategy to reduce risk in farm business. In the first stage a judicious combination of crops is a better protection against adverse weather conditions. If there was excessive rainfall or low temperature, crops like grams, vegetables might fail while jowar would do well. Under moderate rainfall jowar might survive with low yield while other crops like paddy do well. In extreme drought condition most of the crops fail on dry land. Similar protection would be there against uncertain prices and demand conditions in the market. Therefore, crop diversification of farms was largely desired and this was measured by crop diversification index. In the canal and tank irrigated areas the calculated crop diversification index was 1.18 and 0.91, respectively. This is 1.3 times greater than the latter. Thus diversification of crop mix that allowed protection against risk and enabled more efficient use of land and water by the agriculturists which are considered scarce resources in agriculture practice.

##### ***5. Cropping and Irrigation Intensities***

Cropping intensity index referred to the ratio of gross cropped area to the net area sown expressed in percentage. Irrigation intensity index referred to the ratio of gross irrigated area to the net irrigated area expressed in percentage. These two measures indicates the efficiency with which the farmers have made use of the available land and water. Cropping and irrigation intensities are expressed in Table V.

**TABLE. V**  
**CROPPING AND IRRIGATION INTENSITIES OF**  
**SAMPLE FARMS IN THE STUDY AREAS**

*( in hectares)*

<i>S.No</i>	<i>Items</i>	<i>canal irrigated area</i>	<i>Tank irrigated area</i>
1	Net area sown per farm	2.85	2.07
2	Gross cropped area per farm	5.03	2.86
3	Net irrigated area per farm	2.77	1.95
4	Gross irrigated area per farm	4.98	2.67
5	Cropping intensity Index	176.49	138.16
6	Irrigation intensity Index	179.79	136.92

The cropping intensity was higher (176.49 percent) in canal irrigated area than in tank irrigated area (138.16). Similarly, irrigation intensity was also high (179.78 percent) in canal irrigated area as against that of tank irrigated area (136.92 percent). Both irrigation intensity and cropping intensity were high in canal irrigated area because of the availability of water for use in canal and wells for raising two or more crops in most of the lands during the study period. Tank irrigated area depended on tank and well irrigation. The water availability depended upon the rainfall pattern.

#### **6. *Farm Assets***

The value of farm assets serves as a measure of the economic viability and liquidity of the farm business. The asset position of farms of both the areas is presented in Table VI.

**TABLE VI**  
**MEAN ASSETS OF THE FARM HOUSEHOLDS IN THE**  
**STUDY AREAS**

( in Rupees)

<i>Sen.</i>	<i>Assets</i>	<i>Canal Irrigated Area</i>	<i>Tank Irrigated Area</i>
1	Land	7,01,870 (65.06)	5,58,090 (73.43)
2	Farm buildings	1,30,240 (12.07)	80,470 (10.59)
3	Irrigation Structure and Tools	29,850 (2.77)	28,470 (3.75)
4	Machinery and Implements	1,86,330 (17.27)	67,240 (8.86)
5	Live stock	50,580 (2.83)	25,570 (3.36)
6	Total	10,78,860 (100)	7,60,120 (100)

Note : The figures in the parentheses indicate the percentages to the total.  
The figures may not add to the total due to rounding off to the nearest ten rupees

The value of mean assets in the possession of a farm household was Rupees 10.7 lakhs in the canal irrigated area and it was rupees 7.6 lakhs at the command of a farm in the tank irrigated area. As one expects, land formed the major asset in both the study areas accounting for more than 65 percent of the total value of the farm assets.

The higher share of land in tank irrigated area than canal irrigated area might be due to well irrigation and tank irrigation facilities in the former region which increased the value of land. Machinery and farm implements formed the next important asset in canal irrigated area. Since the farmers of canal irrigated area have to carry out the farm operations simultaneously when water is let in Bhavani canal, it would necessitate the farm implements and machinery for timely operation. This would have been the reason for high investment in machinery and implements in canal irrigated area.

#### ***B. Input Use Behaviour on Sample Farms***

A resource or input factor is considered to be used most efficiently if its marginal value product is just sufficient to offset its cost. An important measure of decision making process is the economic efficiency. To study the efficiency in use of inputs, "*ceteris paribus*", a whole farm production function was specified in Cobb Douglas form and estimated after log

transformation. The whole farm production was measured by the aggregate money value of products, valued at average prices received by the sample farmers. The use of sample average prices eliminated the problem of interfarm variation in income due to prices. The production function was then used to estimate the probabilistic frontier production function (PFPF) and stochastic frontier production function (SFPF hereafter).

Use of pumpsets, tractors and tractor based machineries helped the farmers to augment irrigation facilities and to carry out the operations in time. To intensify cultivation and to diversify cropping pattern, the farmers have to use complementary inputs such as human labour, fertilisers, manures and quality seeds. Consequently, resource use efficiency as measured by the marginal productivity of resources would change. This change in resource use efficiency is important for the study.

A distinction was made between average production function and frontier function which would show average and maximum productivity of resources respectively. Allowing for inter-farm variation a stochastic frontier production function was the choice and a probabilistic frontier production function was also used to overcome difficulties in making assumptions concerning joint distribution of random error and technological coefficients.

### **1. Farm Production Function in Canal Irrigated Area:**

The estimated parameters of the average production function SFPF and PFPPF for farms in canal irrigated area is presented in Table VII

**TABLE VII**  
**Estimated Coefficients of Production Functions of Farms - Canal Irrigated Area**

S.No.	Functional Forms	No. of Farms	Intercept	Farm Size X1	Human Labour X2	Crop diversification index X3	Animal and Machine Power X4	Fertiliser X5	R <sup>2</sup>	F	Returns to Scale
1	Average production function OLS	70	273.93	.1312 (.1093)	2501* (.9183)	.4017* (.1631)	-.1309* (.0389)	.2604 (.1131)	.8301	38.149	.9125
2	SFPF (COLS)	70	394.19	.1312 (.1093)	2501* (.9183)	.4017* (.1631)	-.1309* (.0389)	.2604* (.1131)	.8301	38.149	.9125
3	SFPF (MLE)	70	415.31	.1501 (.1179)	2539 (.1378)	.4101* (.1716)	-.1209* (.0410)	.2901* (.1309)	.8692	48.932	.9833
4	PPPF93	65	42134	.1013 (.1319)	2618 (1396)	.4192 (.1492)	-.1200* (0394)	.2893* (1421)	.8512	45.527	.9516
5	PPPF88	60	424.19	.1037 (.0978)	2679 (.1492)	.4159* (.1590)	-.1231* (.0791)	.2812* (.1273)	.8561	49.279	.9556
6	PPPF81	57	425.75	.1191 (.1211)	2687* (.1342)	.4098* (.1423)	-.1201* (.0789)	.2892 (.1379)	.8598	48.729	.9667
7	PPPF79	55	424.33	.1107 (.1391)	2671* (.1231)	.4121* (.1329)	-.1212* (.09122)	.2817 (.1379)	.8601	49.791	.9504

Note: (i) The figures in the parentheses are the standard error of the estimates.

(ii) \* Significant at 5% level.

(iii) OLS - Ordinary Least Square.

(iv) COLS - Corrected Ordinary Least Squares.

(v) SFPF - Stochastic Frontier Production Function

(vi) PFPF - Probabilistic Frontier Production Function. The figure attached to them indicate the percentage of farms covered.

(vii) Corrected ordinary least square estimates had the intercept 394.14 and is 43.89 percent higher than that of OLS estimates.

(viii) The relative variability coefficient  $\gamma = .8332$  (.3712)

(ix) Log likelihood function = -12.141,

$$\hat{\sigma}^2 = 1.76 \quad \hat{\sigma}_u^2 = 1.465 \quad \hat{\sigma}_v^2 = .295$$

All the estimated coefficients showed a good fit with the value of coefficient of multiple determination  $R^2$  being higher than 0.8301 with F ratio which was statistically significant. The elasticity coefficient of farm size had positive sign but was not statistically significant in all the estimated functions implying that farm size had no influence on farm income. It is mostly because, inter-farm variation in farm size was small (coefficient of variation was small and it was 15.23 percent). The elasticity coefficient of animal and machine power had an unexpected negative sign consistently in all functions which were also statistically significant. The inference was that animal and tractor power was over used on farm and it should be reduced. This has very important implications : already farmers did not find enough use of tractor and tractor based equipments and depend on custom hiring, even then tractor use was less than its fullest capacity. Reducing on-farm use further would require a search for opportunities to hire out for off-farm and non-farm use for still more number of hours.

Crop diversification index, human labour and fertiliser use had positive coefficients with numerical values less than unity implying that these resources operate in the rational region of production. This result is in accordance with the studies conducted in various regions of India by

Shyamal(1971), Ramachandran(1979), Kalirajan (1990) and Palanisamy (1993).

The sample farms exhibited the constant returns to scale i.e  $\sum \beta_i$ , the sum of the elasticity coefficients which ranged from 0.9125 to 0.9833. It supported the assumption of constant returns to scale in the determination of PFPFs by minimising linear sum of residuals. This finding confirmed the results of the earlier investigations conducted in various regions of India over years (Lau and Yotopoulos 1971, Yotopoulos and Lawrence 1973, Ramachandran 1979). The estimated less than unity value of returns to scale (though statistically not different from one) of farms in canal irrigated area could be because the excluded factor inputs varied less proportionately with changes in the included factor inputs over the sample of observations (Heady and Dillon 1960).

The PFPF attained stability of parameters after deleting 21 percent of outliers (observations) i.e. PFPF 79. The parameters of SFPPF (estimated by MLE) seemed to be almost equal to those of PFPF 79. All the co-efficients of SFPPF were greater than that of OLS estimates. The intercept term of SFPPF (COLS estimate) was about 44 percent higher than that of OLS estimates of the function and this indicated that the best practice production function had shifted neutrally (Hicks neutral) from the average production function. Meeusen and Broeck (1977) and Battese and Corra (1977) obtained similar

results. However, this neutral shift could be because of the technique selected to estimate SFPP (Kalirajan 1981). Bravo-Ureta (1986) obtained similar results in the estimation of PFPF. This might be partially due to deletion of certain percentage of observations. This comparison strongly suggested that at least some of the sample farms were exploiting the potential of the best practiced technique of production.

The parameter  $\gamma$  (indicator of relative variability of  $u_i$  and  $v_i$ ) was 0.8332 and significant. This implied that the deviation of a given farm's actual yield from the maximum feasible yield was caused mostly by the farmer's failure to use the best practices. This finding confirmed the results of earlier investigations conducted in various regions of India Kalirajan (1981).

The value of  $\sigma_u^2$  at 1.465 was different from zero. It implied that symmetric error  $v_i$  is not predominant error. A given farm's yield differed from maximum feasible yield mainly because of factors under control, i.e., inappropriate allocation of inputs and technology. The productivity differences were mainly related to sample participant's lack in the use of best practices. This could imply that the homogeneity assumption, i.e., the timely availability of inputs in required quantities for production condition is not valid for the study area and there could be differences in use of inputs. However, the secondary data suggested that the homogeneity assumption could be valid for conventional inputs. Further it could be

invalid in relation to the use of nonconventional inputs such as rainfall and weather conditions. Technical inefficiency may have been caused by nonavailability of proper and timely technical advice and the inability of the farmers to apply effectively the farm management techniques on time. This might be due to non-adoption of technology correctly.

## **2. Farm Production Function in Tank Irrigated Area:**

The estimated parameters of average production function, SFPPF and PFPPF for farms in tank irrigated area are presented in Table VIII

TABLE VIII

## Estimated Coefficients of Production Functions - Tank Irrigated Area.

S.No	Functional Form	No. of farms	Intercept	Farm Size X1	Human Labour X2	Crop Diversification Index X3	Animal & Machine Power X4	Fertiliser X5	R <sup>2</sup>	F	Returns to scale
1	Average production function OLS	60	341.72	.1134* (.0378)	.2012 (.1931)	.4103* (.1191)	.0712 (.1432)	.2019* (.0871)	.832	48.73*	.9440
2	SFPF (COLS)	60	512.89	.1134 (.0378)	.2012 (.1931)	.4103* (.1191)	.0172* (.1432)	.2019* (.0871)	.832	48.73*	.9440
3	SFPF (MLE)	60	602.73	.1431* (.0549)	.2101 (.1989)	0.4109* (.1819)	-.0180* (.1452)	.262* (.0891)	.8491	49.79	.9841
4	PFPF95	57	379.12	.1179* (.0521)	.2019 (.1910)	.4003* (.1091)	.0191 (.1372)	.2009 (.0912)	.848	52.12*	.9401
5	PFPF88	53	393.17	.1192* (.0712)	.2102* (.1889)	.4100 (.1201)	.0195 (.1452)	.2103 (.123)	.8591	51.75*	.9689
6	PFPF81	49	395.17	.1181* (.0812)	.2008 (.1813)	.3982* (.1310)	.0191 (.1713)	.2103 (.1075)	.8781	53.76*	.9465
7	PFPF75	45	398.79	.1189* (.0912)	.2021 (.1902)	.3902* (.1411)	.0194 (.1713)	.2109 (.1008)	.8598	52.78*	.9415
8	PFPF72	43	401.06	.1192* (.0891)	.2080 (.192)	.3912 (.1419)	.0196 (.1813)	.2110 (.1193)	.8617	55.79	.9484

Note: (i) The figures in the parentheses indicate the standard error of the estimated and

(ii) \* significant at 5% level, (iii) OLS - Ordinary least squares,

(iv) COLS - Corrected ordinary least squares, (v) SFPF - Stochastic Frontier Production Function.

(vi) PFPF - Probabilistic Frontier Production Function. The figure attached to them indicate the percentage of farms covered

(vii) Corrected ordinary least square estimates had the intercept 512.89 and is 50.09% higher than that of the OLS estimates.

(viii) The relative variability coefficient  $\gamma = .7934$  (.3149)

(ix) The loglikelihood function is 12.1472

$$\hat{\sigma}_u^2 = 2.1317 \quad \hat{\sigma}_v^2 = 1.6913 \quad \hat{\sigma}_v^2 = .4404$$

All functions had statistically significant value of  $R^2$  indicating goodness of fit. Elasticity coefficients obtained for farm size, crop diversification index and fertiliser were significant and for other variables viz., human labour and animal and machine power were not significant. It could be inferred that the farm income was influenced by farm size. All the estimated coefficients were numerically less than unity showing that their use was in economically rational region of production. Compared to OLS estimates, PFPF 72 and SFPF (estimated by MLE method) had larger numerical values for all coefficients associated with inputs. Hence, there may be a chance that these variables would improve technical efficiency of farms. Comparison of OLS estimates with those of (MLE) estimates revealed that the best practice production function did not shift neutrally from the average production function. This result is reasonable to accept because use of machine power enabled more intensive use of land whereas bullock power was required to prepare land and human labour for intercultivation operations. The timely use of bullock power and human labour would have increased efficiency of the farms.

The sum of production elasticities  $\sum \beta_i$  ranged from 0.9400 to 0.9841 which indicated constant returns to scale. The estimated returns to scale (less than unity though statistically not different from one) of tank irrigated area farms might be due to the fact that the excluded inputs varied less

proportionately with changes in the included inputs over the sample of observations.

The intercept of SFPF (estimated by OLS) was 50.09 percent higher than that of the OLS estimates. It indicated that the best practice production function had shifted neutrally from the average production function.

The estimate of  $\gamma$  was 0.7934 and statistically significant implying that the variation of farm yield from maximum feasible yield was mainly due to difference in the use of the best practice of production.  $\sigma_v^2 = 1.6913$  and different from zero implied that the symmetric error  $v_i$  is not predominant. A given farm's yield differed from maximum feasible yield mainly because of the factors under its control, i.e., inappropriate allocation of inputs and technology. The productivity differences were mainly related to sample participant's lack of use of best practices. This could imply that the homogeneity assumption for production conditions is not valid in the study area and that there could be differences in the availability and use of inputs. However, the secondary data suggested that the homogeneity assumption i.e., timely availability of inputs in required quantity in the study area is valid for conventional inputs. Further homogeneity assumption could be invalid in relation to non conventional factors i.e., untimely rainfall and weather conditions, non-availability of proper and timely

technical advice and inability to apply the farm management techniques at appropriate time as done on the technically efficient farms. This might be partially due to the technology being not used correctly.

### ***C. Measures of Efficiency in Sample Farms:***

The farmers in the study area operated the inputs in the rational region of production. As discussed earlier, 21 percent and 28 percent in the canal irrigated and tank irrigated areas, respectively were able to exploit the potentials fully and maximise their output. Their success in maximising the output has been due to the proper choice and allocation of inputs technically. The respective failure of 79 and 72 percent of the farmers to maximise their output in spite of operating in the rational region of production was due to non adoption of technology fully and correctly. This implied that those farmers have not allocated the inputs efficiently and operated efficiently technically also. The study of factors responsible for not realising the maximum output could be classified under two broad categories viz., technical and allocative inefficiencies. These two were studied with the help of economic performance of sample farmers. The economic behaviour of sample farmers in the study areas was examined in terms of economic efficiency of cultivation using profit function and factor demand functions.

The farmers had not reported any shortage in the supply of inputs, like quality seeds, fertilisers, pesticides, rodenticides and herbicides which were

supplied by agricultural depots. Some farmers used seeds grown on their own farms. Though the wage rate of labour for various field operations varied from farm to farm there was no labour shortage in the study areas. It could generally be observed that there was no significant difference in the level of inputs used by the sample farmers in the two areas. Hence, the yield obtained remained almost the same. This might be due to the fact that the crop studied, i.e., paddy required specific levels of inputs under the package of practices irrespective of the areas where it is cultivated. In canal irrigated and tank irrigated areas, paddy was cultivated under irrigated condition and hence the same level of inputs.

The most important criterion for decision making in the production process is economic efficiency. In practice it was found that farms produce the same level of output with varying factor intensities because even if they want to maximise profits they faced different prices for inputs and outputs. But they have fixed factors of production namely land and machinery.

### **1. Technical Efficiency :**

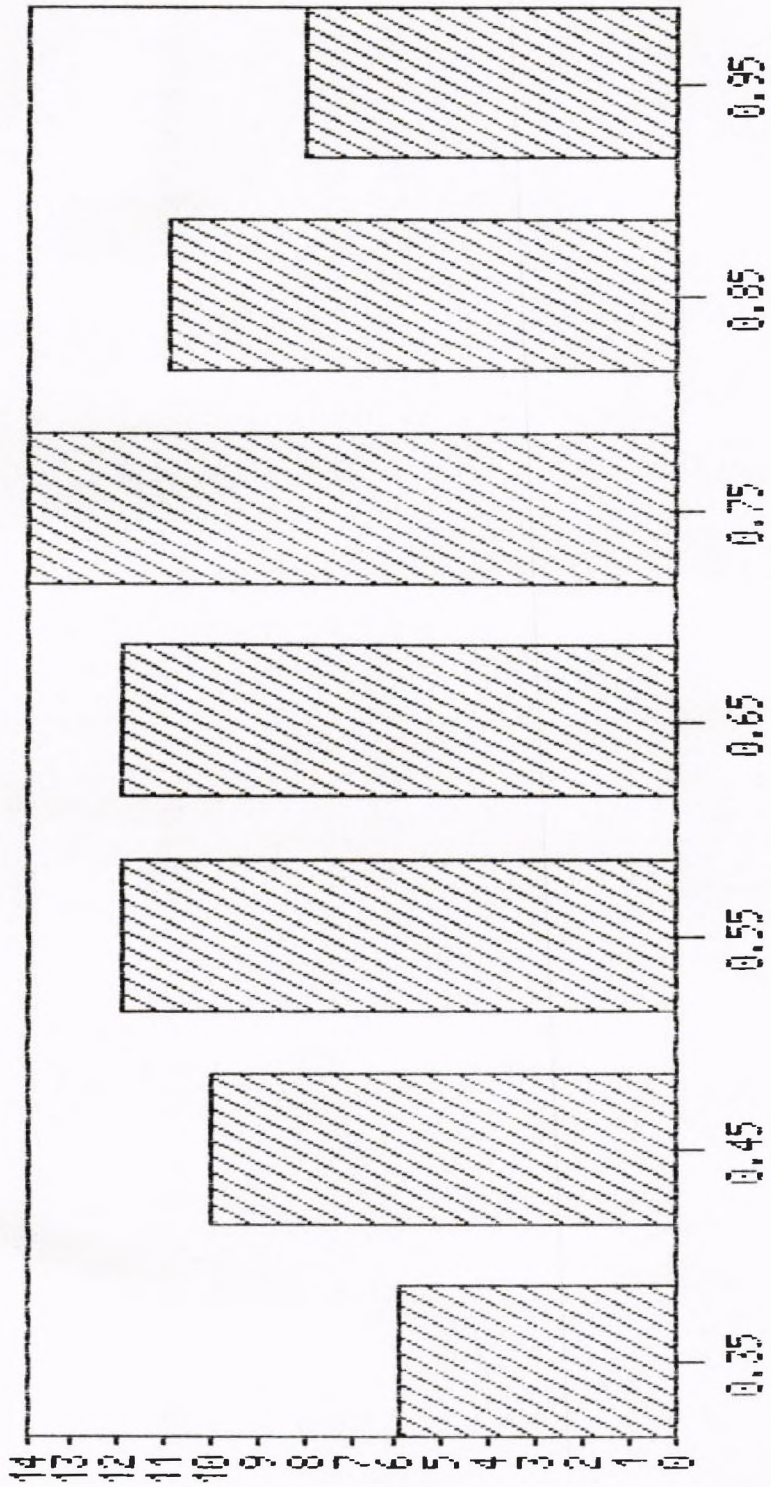
The frequency distribution of technical efficiency of farms from SFPP by COLS and MLE for both areas are presented in Table -IX and are also represented graphically.

**TABLE - IX**  
**FREQUENCY DISTRIBUTION OF TECHNICAL**  
**EFFICIENCY OF FARMS**

Efficiency Interval	Canal Irrigated Area		Tank Irrigated Area	
	COLS	MLE	COLS	MLE
0.30 – 0.40	6 (8.57)	5 (7.14)	7 (11.67)	6 (10.00)
0.40 – 0.50	10 (14.29)	10 (14.29)	8 (13.33)	9 (15.00)
0.50 – 0.60	12 (17.54)	11 (15.71)	7 (11.67)	6 (10.00)
0.60 – 0.70	12 (17.54)	11 (15.71)	7 (11.67)	9 (10.00)
0.70 – 0.80	14 (20.00)	15 (21.43)	8 (13.33)	8 (13.33)
0.80 – 0.90	11 15.71	11 15.71	10 16.67	13 21.66
0.90 – 1.0	8 (11.43)	9 (12.86)	11 (18.33)	10 (16.67)
Total	70 (100)	70 (100)	60 (100)	60 (100)
Mean Efficiency	0.67	0.68	0.67	0.69

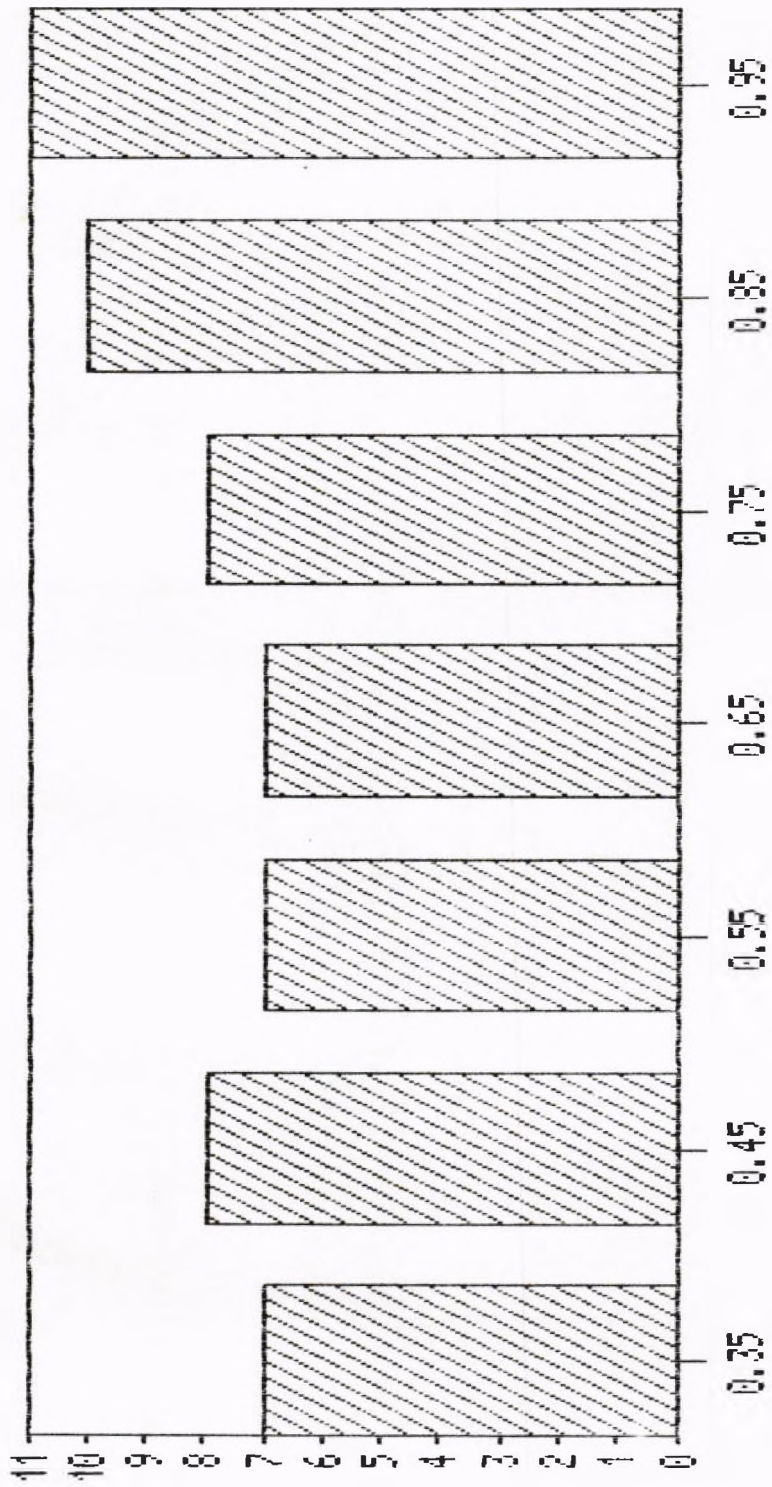
Note : The figures in the parantheses indicate the percentage to the column total

FREQUENCY DISTRIBUTION OF TECHNICAL EFFICIENCY OF FARMS - CANAL IRRIGATED AREA



COLS

FREQUENCY DISTRIBUTION OF TECHNICAL EFFICIENCY OF  
FARMS - TANK IRRIGATED AREA



COLS

The efficiency rating in terms of overall of technical efficiency ranged from 35 percent to 100 percent with eight and ten farms respectively, of canal irrigated area and tank irrigated area exhibiting full efficiency. The overall mean value of efficiency of farms for both areas was ranged from 0.67 to 0.69. Taking COLS method it could be inferred that nearly 40 and 37 percent of farms in canal irrigated area and tank irrigated area are operating below their respective mean efficiency levels. Nearly 11 and 16 percent of the farms operated with 0.90 level of efficiency. The heterogeneity in management skills, production practices and facilities available in farms could explain the distribution of technical efficiency. Similar results were obtained in dairy farms by Weersink et.al, 1990. The difference in prices and fixed non conventional factors of production which results in varying technical efficiencies of farms also could explain the differences in overall economic efficiencies of farms.

## **2. Economic Efficiency:**

Simple measures of economic efficiency are returns to single factor of production like land, labour, animal and machine power, fertiliser use where all factors other than land are valued at market prices. They are also called partial measures of efficiency in literature. However, the assumption that the market price is the same for all producers is not valid in practice. The profit function allows for farms paying different prices for homogeneous variable

factors of production. It allows inter farm differences in equating marginal value product of variable inputs with their prices. Thus the profit function describes economic efficiency incorporating the two components viz. technical and price efficiencies.

In the context of Cobb Douglas production function, unit output price profit function (UOP) was used to examine the relative economic efficiency and find out whether UOP of two groups differed from one another significantly. Given equal access to inputs and technology, the farmers of canal irrigated and tank irrigated areas were expected to have equal relative economic efficiency. In other words, the dummy variable in UOP profit function was hypothesized to have zero co-efficient. This hypothesis of equal relative economic efficiency of farmers of two areas was tested  $H_0: \alpha_0 = 0$  Where  $H_0$  indicates null hypothesis

This hypothesis implied  $\ln A^1 - \ln A^2 = 0$  i.e.,  $A^1 = A^2$

This implied that  $A^1 = A^2$  and  $k^1 = k^2$  and profit functions and variable factor demand functions of both areas of farmers coincide. Tables X and XI indicated that null hypothesis of equal relative economic efficiency could not be rejected at 95 percent level of significance which suggested that the farmers of both areas have equal overall economic efficiency in farming. From the table XII and XIII it could be inferred that the coefficient D1 was not statistically different from zero at 95 percent level. It indicated the existing relative economic efficiency was the same among the farmers of both the areas.

**TABLE - X**  
**JOINT ESTIMATION OF NORMALISED PROFIT FUNCTION AND**  
**VARIABLE FACTOR DEMAND FUNCTION - CANAL IRRIGATED AREA**

Particulars	Parameter	Generalised Least Squares Estimates			
		Without Restriction	Restriction I	Restriction II	Restriction III
Constant	$\lambda$	7.1074** (1.934)	7.3134** (1.4972)	7.2131** (1.7934)	7.1298** (1.5723)
Land	$\ln L$	0.8138** (0.2132)	0.8429* (0.1931)	0.7910** (0.2973)	0.8309** (0.2801)
Labour	$\ln W$	-0.4514* (0.2007)	-0.4210* (0.2013)	-0.4319* (0.1973)	-0.4494* (0.2013)
Machine and Animal Power	$\ln B$	0.1931* (0.0734)	0.1839* (0.0812)	0.1959* (0.0897)	0.1792* (0.0707)
Fertilizer	$\ln F$	-0.7912 (0.5312)	-0.7891 (0.6132)	-0.8100 (0.6892)	0.7941 (0.5923)
Dummy	$\alpha_0$	-0.0732 (0.2431)	-0.0631 (0.1796)	-0.0937 (0.1891)	-0.1033 (0.1073)

Note : Figures in the parentheses are the standard error of estimates

\* - Significant at 5% level

\*\* - Significant at 1% level

D = 1 for farms in Canal irrigated area  
 0 for farms in Tank irrigated area

Restriction I =  $\beta_i^{*p} = \beta_i^{*c}$  for  $i = 1, 2, 3$

Restriction II =  $\beta_i^{*p} = \beta_i^*$  and  $\beta_i^{*c} = \beta_i^c$

Restriction III =  $\beta_i^{*p} = \beta_i^*$ ,  $\beta_i^{*c} = \beta_i^*$  and  $\alpha_1^* + \alpha_2^* = 1$

**TABLE - XI**  
**JOINT ESTIMATION OF NORMALISED PROFIT FUNCTION AND**  
**VARIABLE FACTOR SHARE FUNCTIONS - CANAL IRRIGATED AREA**

Particulars	Parameter	Generalised Least Squares Estimates			
		Without Restriction	Restriction I	Restriction II	Restriction III
Labour Share	$\beta_1^{*p}$	-0.6819* (0.2392)	-0.6310* (0.2303)	-0.6009* (0.2931)	-0.6039 (0.2429)
	$\beta_1^{*c}$	-0.5931* (0.2803)	-0.6001* (0.2792)	-0.5909* (0.2610)	-0.5712* (0.2412)
Fertiliser <i>Shau</i>	$\beta_2^{*p}$	-1.5103* (0.7091)	-1.5194* (0.7791)	-1.4921* (0.7810)	1.4893* (0.7031)
	$\beta_2^{*c}$	-1.8310 (0.6319)	-1.8124 (0.6912)	-1.7391* (0.1612)	1.7421 (0.6132)
Machine Animal power <i>Shau</i>	$\beta_3^{*p}$	-0.0932* (0.0413)	-0.8732* (0.0391)	-0.8979* (0.0391)	-0.0910* (0.0412)
	$\beta_3^{*c}$	-0.0912* (0.0331)	-0.0907* (0.0349)	-0.0859* (0.0352)	-0.0909* (0.0913)

Note : Figures in the parentheses are the standard error of estimates

\* - Significant at 5% level

\*\* - Significant at 1% level

D = 1 for farms in Canal irrigated area  
 0 for farms in Tank irrigated area

Restriction I =  $\beta_i^{*p} = \beta_i^{*c}$  for  $i = 1, 2, 3$

Restriction II =  $\beta_i^{*p} = \beta_i^{*c}$  and  $\beta_i^{*c} = \beta_i^{*c}$

Restriction III =  $\beta_i^{*p} = \beta_i^{*c}$ ,  $\beta_i^{*c} = \beta_i^{*c}$  and  $\alpha_1^{*c} + \alpha_2^{*c} = 1$

**TABLE - XII**  
**JOINT ESTIMATION OF NORMALISED PROFIT FUNCTION AND**  
**VARIABLE FACTOR DEMAND FUNCTIONS - TANK IRRIGATED AREA**

Particulars	Parameter	Generalised Least Squares Estimates			
		Without Restriction	Restriction I	Restriction II	Restriction III
Constant	$\lambda$	6.9130** (1.8947)	6.7191** (1.9173)	6.4123** (1.7910)	6.6710** (1.7891)
Labour	$\ln W$	-0.3914** (0.1791)	-0.3819* (0.1910)	-0.3809* (0.1801)	0.3914* (0.1789)
Fertilizer	$\ln F$	-0.7602 (0.6913)	-0.7719 (0.5931)	-0.7810 (0.5149)	-0.7981 (0.6412)
Machine and Animal Power	$\ln B$	0.1723** (0.0537)	0.1614** (0.0692)	0.1529** (0.0621)	0.1529** (0.0621)
Land	$\ln L$	1.1312 (0.6720)	1.1309* (0.5132)	1.1008* (0.4320)	1.1091* (0.4812)
Dummy	$\alpha_0$	-0.2653 (0.3112)	-0.2441 (0.3108)	0.1710 (0.2610)	0.1810 (0.2510)

Note : Figures in the parentheses are the standard error of estimates

\* - Significant at 5% level

\*\* - Significant at 1% level

D = 1 for farms in Canal irrigated area  
 0 for farms in Tank irrigated area

Restriction I =  $\beta_i^{*p} = \beta_i^{*c}$  for  $i = 1, 2, 3$

Restriction II =  $\beta_i^{*p} = \beta_i^*$  and  $\beta_i^* = \beta_i^{*c}$

Restriction III =  $\beta_i^{*p} = \beta_i^*$ ,  $\beta_i^{*c} = \beta_i^*$  and  $\alpha_1^* + \alpha_2^* = 1$

**TABLE - XIII**  
**JOINT ESTIMATION OF NORMALISED PROFIT FUNCTION AND**  
**VARIABLE FACTOR SHARE FUNCTIONS – TANK IRRIGATED AREA**

Particulars	Parameter	Generalised Least Squares Estimates			
		Without Restriction	Restriction I	Restriction II	Restriction III
Labour Share	$\beta_1^{*P}$	-0.5413** (0.2146)	-0.5318** (0.2278)	-0.5217** (0.2209)	-0.5109** (0.2301)
	$\beta_1^{*c}$	-0.5012* (0.2012)	-0.5003* (0.2002)	-0.5108* (0.2018)	-0.4979** (0.1978)
Fertiliser <i>Share</i>	$\beta_2^{*P}$	-0.8134 (0.6971)	-0.7907 (0.7120)	-0.7991 (0.7301)	-0.6978 (0.7014)
	$\beta_2^{*c}$	-0.8314 (0.5398)	-0.8712 (0.5912)	-0.8619 (0.5817)	-0.9012 (0.5912)
Machine Animal power <i>Share</i>	$\beta_3^{*P}$	-0.3229** (0.0934)	-0.3029** (0.0991)	-0.2918** (0.0919)	-0.2988** (0.1172)
	$\beta_3^{*c}$	-0.3314** (0.1121)	-0.3516** (0.1217)	-0.3479** (0.1148)	-0.3397 (0.1078)

Note : Figures in the parentheses are the standard error of estimates

\* - Significant at 5% level

\*\* - Significant at 1% level

D = 1 for farms in Canal irrigated area  
0 for farms in Tank irrigated area

Restriction I =  $\beta_i^{*P} = \beta_i^{*c}$  for  $i = 1, 2, 3$

Restriction II =  $\beta_i^{*P} = \beta_i^*$  and  $\beta_i^* = \beta_i^{*c}$

Restriction III =  $\beta_i^{*P} = \beta_i^*$ ,  $\beta_i^{*c} = \beta_i^*$  and  $\alpha_1^* + \alpha_2^* = 1$

### 3. Test of Equality of Price Efficiency

Testing of equality of price efficiency involves a combination of tests of equality of relative price efficiency and absolute price efficiency.

#### a. Equality of Relative Price Efficiency

Test of equality of relative price efficiency of the farmers of the two areas implied that the marginal value product is equal to the marginal costs for both. That is, in other words, the elasticities of variable inputs of farms of canal irrigated area ( $\beta_i^{*p}$ ) and farms in tank irrigated area ( $\beta_i^{*c}$ ) estimated from factor demand functions must be the same. This may be referred to as Restriction - I. It is one of the restrictions employed in the estimation of normalised profit functions, factor share function and factor demand function. Equal relative price efficiency was tested with hypothesis

$$H_0 : \beta_i^{*p} = \beta_i^{*c} \text{ for } i = 1,2,3,4$$

The equivalence of parameters need not necessarily indicate perfect maximisation and does not indicate that farmers of both areas succeeded to the same degree in profit maximisation. This analysis is presented in Table XIV.

**TABLE - XIV**  
**COMPARISON OF THE RESULTS OF STATISTICAL TESTS OF THE**  
**SAMPLE FARMS OF TWO AREAS**

Restrictions used	Lagrange Multiplier $\lambda$	Showing the validity of restrictions taken together $\chi^2$
$\beta_1^{*P} = \beta_1^{*c}$	0.2093 (0.6342)	3.9812
$\beta_2^{*P} = \beta_2^{*c}$	1.1739 (1.2912)	
$\beta_3^{*P} = \beta_3^{*c}$	0.8349 (0.5478)	
$\beta_1^{*P} = \beta_1^{*c}$	0.4812 (0.3433)	4.7230
$\beta_2^{*P} = \beta_2^{*c}$	1.9721 (1.7314)	
$\beta_3^{*P} = \beta_3^{*c}$	3.4720 (0.9123)	
$\beta_1^{*P} = \beta_1^{*c}$	0.3972 (0.3712)	6.1248
$\beta_2^{*P} = \beta_2^{*c}$	1.7391 (1.0810)	
$\beta_3^{*P} = \beta_3^{*c}$	4.9121 (0.1131)	
$\alpha_1^* + \alpha_2^* = 1$	0.1315 (0.5470)	

The results of the analysis reveal that the null hypothesis of equal relative price efficiency cannot be rejected at 5 percent level because the value of  $\lambda$  did not differ significantly from zero as  $\chi^2$  was not significant it implied that the restrictions were satisfied and hence there is no difference in equality of relative price efficiency between the farms of the two areas.

#### b. Equality of Absolute Price Efficiency

Test for absolute price efficiency is based on maximising the profit function of canal irrigated area and tank irrigated area farmers and equating their marginal value product to marginal cost at the variable factor price. For this purpose, the elasticities of variable factors viz.,  $\beta_i^{*p}$  and  $\beta_i^{*c}$  estimated from factor demand functions must be equated to the respective elasticities  $\beta_i^{*}$  estimated from UOP profit function i.e.,  $\beta_i^{*p} = \beta_i^{*}$ ,  $\beta_i^{*c} = \beta_i^{*}$ . Hence, this absolute price efficiency of farms of canal irrigated area  $H_0: \beta_i^{*p} = \beta_i^{*}$  and the absolute price efficiency of farms of tank irrigated area  $H_0: \beta_i^{*c} = \beta_i^{*}$ . These two were referred to as restriction II and III employed in the estimation of functions.

In other words it is equivalent to testing the statistical hypothesis:

$$H_0: \beta_i^{*c} = \beta_i^{*}, \beta_i^{*p} = \beta_i^{*}$$

It is inferred that null hypothesis of equal absolute price efficiency of farmers of both areas could not be rejected at 5 percent level because

estimated of  $\lambda$  did not differ significantly from zero (vide Table XIV). This also revealed that the restrictions were satisfied and there were no differences between price efficiency parameters of farmers of both areas. So it could be inferred that the farmers of the two areas showed the same degree of maximization.

#### 4. Equality of Relative Technical Efficiency

The null hypothesis of equal relative technical efficiency between the farmers of both the areas was tested by

$$H_0: \alpha_0 = 0 \quad \text{and}$$

$$\beta_i^{*P} = \beta_i^{*c} \quad \text{for } i = 1, 2, 3, 4$$

Test for equal relative technical efficiency consists of testing joint equal relative economic and equal price efficiencies.

$$H_0: \alpha_0 = 0 \quad \text{and}$$

$$H_0 = \beta_i^{*P} = \beta_i^{*c}$$

The results of the analysis (vide Table XIV) indicated that the farmers of both the areas were equally efficient economically and were equally price efficient since the value of  $\chi^2$  was not significant at 5 percent level. This further implied that they were equally technically efficient. The equality of the price efficiency parameters in both profit functions of farmers of two areas was a necessary condition in statistical testing of profit maximisation. Thus for perfect profit maximisation

$$H_0: \beta_s^P = B_s^*$$

The results of tests of absolute price efficiency of farmers of canal irrigated area (Table XII) showed that the above null hypothesis cannot be rejected at 5 percent level of significance implying that the farmers of canal irrigated area maximised their profit in relation to the levels of use of the variable factors of production. Similarly, the results of the tests of absolute price efficiency of farmers of tank irrigated area (Table XIII) showed that null hypothesis ( can be accepted at 5 percent level of significance. This revealed that the farmers of this area also maximised their profit in relation to the levels of the variable factors of production.

A test for constant returns to scale in the use of factors of production was used to confirm further the existence of equal relative efficiency in production based on the validity of profit maximisation among the sample farmers of the two areas.

The hypothesis  $H_0 = \alpha_1^0 + \alpha_2^* = 1$  indicated that constant returns to scale in all factors of production prevailed provided the parameters of fixed factors of production in profit function added to unity (Yotopoulos and Lau 1971). This hypothesis  $H_0 = \alpha_1^0 + \alpha_2^* = 1$  along with restriction II formed restriction III used in the estimation. This hypothesis was accepted at 5 percent level of significance reinforcing the earlier finding of equal relative efficiency among the farmers of the two areas (vide Table XIV).

Empirical studies had indicated that technical and allocative efficiencies are positively correlated (Hoch, 1958; Page, 1980; Schmidt and Lovell, 1980; and Zellner, 1966). If farmers knew the parameters of the production

frontiers and market with certainty and aimed to maximise profit, they could achieve both technical and allocative efficiencies. To the extent of their knowledge of best practice method of technology is imperfect, there is likely to be technical and allocative inefficiencies. Kalirajan and Shand(1992) attempted to establish empirically a casual relationship between technical and allocative efficiencies. They found that there is a unidirectional casualty from technical efficiency to allocative efficiency. The results of the present study support their results.

## Summary and Conclusion

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## ***V. SUMMARY AND CONCLUSION***

The performance of farms in relation to their efficiencies is a vital area of study, given the need to increase urgently the food production further in future to meet the needs of the growing population and the importance of the fertiliser, seed technology in agriculture. Studies reveal that the average farm yield of crops is, in general, far below the potential. These productivity differences in farms might be due to lack of use of recommended or optimum practices and also due to allocative inefficiencies. With this view, the present study on Assessment of Efficiency : An Application to Paddy Cultivation in Tamilnadu was undertaken to study the existing input use behaviour of the farmers to measure the technical , allocative and economic efficiencies through frontier models and to suggest policies to improve the farming efficiencies of farmers and in turn increase the food grains production.

Periyar and Chengai MGR districts were selected purposively for the present study. These two districts had a major area under paddy cultivation. Periyar represented well and canal irrigation system and Chengai MGR area represented tank and well irrigation system. The

data were drawn from the ongoing Scheme on CCPC operated by the Tamilnadu Agricultural University covering 130 farms in the study area, all of which cultivated paddy. The data pertained to the agricultural year 1993-94.

The major objective of the study was to evaluate the production efficiencies of farms. For this purpose frontier concept was applied. Stochastic frontier production function (SFPPF) and the probabilistic frontier production frontier (PFPPF) were also estimated by applying chance constrained programming to the inequality restrictions so that some observations could be permitted to lie above the estimated frontier. For a given technology and endowment of fixed factors of production the profit function expressed the maximised profit of the farm as a function of the quantity of variable factors of production and factor demand functions. Hence, profit function and factor demand functions were used as an operational model to measure and compare economic efficiencies and its components of technical and price or allocative efficiencies of sample farms.

### ***Findings***

The key findings of the study are summarised below.

**Farm Profile :**

1. The mean operated farm size in canal irrigated area ( 2.95 ha) was higher than that of the tank irrigated area (2.20 ha).
2. The mean farm family size in tank irrigated area had a larger family size than that of the canal irrigated one.
3. The mean earners per family in the two areas ranged between 2 and 3.
4. Only nine out of 130 farmers were found illiterate in the sample and others had had formal education. The level of education found among the farmers could definitely be a positive factor motivating them towards the adoption of new crop production technologies. Being progressive by virtue of their education, the sample farmers could be expected to be favourably disposed towards adoption of new technologies.
5. The principal crop accounting for 52 percent of cultivated area in both the study regions, was paddy, followed by sugarcane which was cultivated in 20 to 23 percent of the area. Banana, groundnut and millets were also grown.

6. The crop diversification index reflecting the intensive use of scarce resources like land and water and the degree of protection against the risk factors to the farmers was higher in canal irrigated area(1.2)as against in tank irrigated area (0.9).
7. Similarly, the cropping intensity as well as irrigation intensity were higher in canal irrigated area at 176 percent and 180 percent respectively as against 138 percent and 137 percent in the tank irrigated area.
8. Land was the major asset of the farm households accounting for 65 percent to 73 percent of its assets.
9. The farmers in canal irrigated area used more machinery and implements as compared to their counterparts in the tank irrigated area. The value of machinery and implements possessed by them was assessed at 17 percent of the mean assets reported by them as against 9 percent under this head in the other group.

### **Input Use Behaviour**

10. In canal irrigated area all the estimated production functions OLS, COLS, SFPP and PFPF had shown a good fit with  $R^2$  ranging from 0.83 to 0.88.
11. The intercept term of SFPP (COLS) estimate was about 44 percent higher than that of OLS estimate of the function indicating that the best practice production function had shifted upward from the average production function. The PFPF function stabilised at 79 percent implying that 21 percent of farms were using the best practice technique.
12. The farm size apparently did not influence farm income in canal irrigated area.
13. The elasticity coefficients of animal and machine power turned out to be statistically significant negative signs indicating their over use on the farm.
14. The coefficients of crop diversification index, human labour and fertiliser use were positive co-efficients less than unity indicating as a contributing factors as farm income.

15. The sample farms in canal irrigated area had shown constant returns to scale.
16. The parameter  $\gamma$  was estimated as 0.8332 and it was also statistically significant showing that the deviation of a given farm's actual yield differ from the maximum feasible yield was explained by the farmers' failure to use the best practices.
17. The production functions estimated for the sample farms in the tank irrigated area also reported a good fit.
18. Unlike the canal irrigated area, the farm size showed up with a positive elasticity co-efficient exhibiting the positive contribution made by land factor to net farm income in the tank irrigated area.
19. The other variables which had a positive coefficient were crop diversification index and fertiliser use.
20. Human labour, animal and machine power did not make a significant contribution to the net farm income.
21. The use of all the inputs were in the economically rational region of production.

22. The sample farms in tank irrigated area also exhibited constant returns to scale.
23. The  $\gamma$  was 0.7934 and statistically significant implying the variation in farm yield from maximum feasible yield was due to the difference in the use of best practices of production techniques.
24. The intercept of SFPPF estimated by COLS was 50 percent higher than OLS production function, PFPF showing that the best practice production function was higher than the average production function.

**Efficiency Parameters:**

25. The mean value of technical efficiency of farmers in both the study areas was in the range of 0.67 to 0.69 with individual variations in the range of 0.35 to 0.95.
26. Thirty five percent of the farms in canal irrigated area and forty six percent of the tank irrigated area operated at less than the mean efficiency levels.
27. The maximum efficiency level of 0.95 was registered by a minimum of 11 percent farms in canal irrigated area and 17 percent of farms in tank irrigated area.

28. The farmers of both areas had reported equal relative economic efficiency, since the hypothesis that the coefficient of dummy variable was equal to zero in UOP could not be rejected.
29. The components of equal price efficiency namely equal relative price efficiency and equal absolute price efficiency, when examined, supported the existence of equality between groups. The null hypothesis of equal relative price efficiency was supported as that of equal absolute price efficiency.
30. The absence of any difference between groups of farmers in terms of technical efficiency was also confirmed.
31. The equality of price efficiency between two groups of sample farmers was confirmed further by the test of constant returns to scale.

By and large no ~~perceptible~~ <sup>significant</sup> differences was observed in relation to technical or allocative efficiencies between the farms in canal irrigated and tank irrigated areas. The farmers in the study areas were operating in the economically rational second region of production and they experienced constant returns to scale. The mean technical efficiency

rating, which was around sixty six percent. About 35 percent and 40 percent of farms in the study areas were operating below the mean level 0.67.

#### **Suggestion for Further Research :**

- Efficiency studies on an ongoing basis may be commissioned by the Department of Agriculture of the Government of India to assess the efficiency of inputs use in relation to different crops.
- Inter relationship between extension services and efficiencies may be explicitly examined .
- Factors behind the individual variations in efficiency may constitute yet another area of research.

#### **Policy Implications :**

- The existence of constant returns to scale may not make farming very attractive to the farmers. More scientific innovations are needed to make farming profitable by way of augmenting productivity.
- The extension services with stress on farm management skills may have to focus on 35 percent and 45 percent of the farmers who were found to be operating below the mean level of technical efficiency.

- The causes for the negligible contribution of farm size to net farm income in tank irrigated area need further probe. Perhaps it implies over use of soil in the region and crop scientists may consider evolving soil conservation strategies for the area.
- Output price has a strong bearing on returns to scale . In agricultural operations, whenever output prices increase, the government intervenes immediately to regulate the prices. While industry has the advantage to raise the prices according to the cost of production. If this kind of apparent discrepancies were removed by the government, the returns to scale will be more beneficial. The government may consider giving agricultural sector similar status as that of the industry.

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# Appendices

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## APPENDIX - I

### TABLE

### DESCRIPTION

- i. DEMOGRAPHIC FEATURES OF THE STUDY AREAS
- ii. DISTRIBUTION OF POPULATION AMONG WORKERS AND NON-WORKERS
- iii. RAINFALL PATTERN IN THE STUDY AREAS
- iv. LAND UTILISATION PATTERN IN THE STUDY AREAS
- v. DISTRIBUTION OF OPERATIONAL HOLDINGS IN THE STUDY AREAS
- vi. NET AREA IRRIGATED BY DIFFERENT SOURCES IN THE STUDY AREAS
- vii. AREA UNDER PRINCIPAL CROPS
- viii. LIVE STOCK AND POULTRY POPULATION IN THE STUDY AREAS
- ix. INPUT AVAILABILITY IN THE STUDY AREAS

**TABLE – i**  
**DEMOGRAPHIC FEATURES OF THE STUDY AREAS**

S.No.	Particulars	Canal Irrigated Area			Tank Irrigated Area		
		Male	Female	Total	Male	Female	Total
1	Total Population	1185256 (51.00%)	1135007 (48.92%)	2320263	2374653 (51.03%)	2278900 (48.97%)	4653593
2	Rural Population	891517 (51.03%)	855476 (48.97%)	1746993	1298354 (50.61%)	1267229 (49.39%)	2555583
3	Urban Population	293739 (51.24%)	279531 (48.76%)	573270	1076339 (51.55%)	1011671 (48.45%)	2088010
4	Literate Population	693866 (62.12%)	423030 (37.88%)	1116896	1570277 (59.30%)	1077820 (40.70%)	2648097

Sources: Techno Economic Survey of Periyar, Chengai MGR districts Tamil Nadu Agrl University, Coimbatore. Census of India 1991 Supplement table, Tamil Nadu Directorate of census operation Madras.

**TABLE – ii**  
**DISTRIBUTION OF POPULATION AMONG WORKERS AND NON WORKERS**  
**(Persons (000))**

Sl.No	Particulars	Canal Irrigated Area	Tank Irrigated Area
1	Cultivators	274235	273563
2	Agriculture Labours	450036	569341
3	House hold industry manufacturing service	46944	64943
4	Other workers	381195	232281
6	Marginal workers	61150	79349
7	Total workers	1213560	1219477
8	Non workers	1106703	2882267

Source : Census of India 1991 Tamil Nadu directorate of census

**TABLE - iii**  
**RAINFALL PATTERN IN THE STUDY AREAS**

Year	Canal Irrigated Area	Tank Irrigated Area
1985	1437.70	1698.4
1986	775.60	996.2
1991	685.40	1453.2
1993	660.00	982.6
Normal rain fall	717.00	1165.3

Source: Agro stat 1994 commissioner of Agriculture Madras Techno Economic Survey of Periyar District CARDS TNAU Coimbatore

**TABLE – iv****LAND UTILISATION PATTERN IN THE STUDY AREAS**

S.No.	Classification	Canal Irrigated Area	Tank Irrigate Area
1	Geographical area	822877	7885453
2	Forest	232832 (28.3)	43592 (5.55)
3	Barren and cultivable land	755563 (0.9)	28912 (3.68)
4	Land put non agricultural use	62693 (7.6)	210292 (26.77)
5	Cultivable waste	3831 (0.5)	19973 (2.52)
6	Permanent Pasture and other grazing land	1192 (0.9)	225001 (3.18)
7	Land under Miscellaneous use	1827 (0.2)	14907 (1.89)
8	Current fallow	36027 (16.5)	77694 (9.90)
9	Other fallow	53274 (6.5)	365558 (4.65)
10	Net area sown	323638 (39.4)	328724 (41.85)
11	Area sown more than once	38225 (4.6)	91956 (11.71)
12	Total cropped	361863 (43.9)	420680 (53.58)

Source: Season and Crop Report of Tamil Nadu for the Agriculture 1991-92

**TABLE – v****DISTRIBUTION OF OPERATIONAL HOLDINGS IN THE STUDY AREAS**

S.No	Size of the holding (ha)	Canal Irrigated Area	Tank Irrigated Area
1	0.0-0.45	110346 (37.32)	361348 (62.65)
2	0.5-0.99	57466 (19.44)	106601 (18.36)
3	1.0-1.99	58462 (19.77)	52339 (11.60)
4	2.0-2.99	27024 (9.14)	22039 (3.79)
5	3.0-3.99	14430 (4.88)	9916 (1.71)
6	4.0-4.99	9159 (3.18)	49660.85)
7	5.0-6.99	1002293.39)	5029 (0.86)
8	7.0-9.99	4487 (1.52)	1179 (0.20)
9	10.0-20.0	3651 (1.23)	1625 (0.28)
10	20 & above	632 (0.21)	431 (0.007)
	Total	295679 (100)	580470 (100)

Source: Season and Crop Report of Tamil Nadu for Agricultural year 1991-92

**TABLE – vi**  
**NET AREA IRRIGATED BY DIFFERENT SOURCE IN THE STUDY AREAS**  
**(ha.)**

S.No.	Particulars	Canal Irrigated Area	Tank Irrigated Area
1	Canals	97703	4015
2	Tanks	379	141145
3	Tube wells, Wells	59183	98980
4	Other sources	160180	79935
5	Gross area of crop Irrigated (ha)	196724	327300

Source: Season and Crop Report of Tamil Nadu for Agricultural year 1993-94

**TABLE – vii**  
**AREA UNDER PRINCIPAL CROPS (ha.)**

S.No	Crops	Canal Irrigated Area	Tank Irrigated Area
1	Paddy	75558	264409
2	Cereals	126412	273729
3	Surgane	14913	12690
4	Pulses	29945	14557
5	Oilseeds		35548
6	Cotton	6807	154
7	Non food crops		22457
8	Total food crops	156357	

Source: Season and Crop Report of Tamil Nadu for the agricultural year 1993-1994

**TABLE – viii**  
**LIVESTOCK AND POULTRY POPULATION**

S.No.	Particulars	Canal Irrigated Area	Tank Irrigated Area
1	Cattle	936034	744758
2	Buffaloes	281731	337647
3	Sheep	79820	328948
4	Goaf	642410	327093
5	Pig	10658	18475
6	Poultry	1390895	1281329

Source : Commissioner of statistic, Chennai Tamil Nadu Economic Appraisal 1993-94

**TABLE – ix**  
**INPUT AVAILABILITY IN THE STUDY AREAS**

S.No.	Particulars	Canal Irrigated Area	Tank Irrigated Area
1	Nitrogen N	28	36
2	Phosphate	10	14
3	Potash	12	11
4	Total	50	61
5	Dust (Tonnes)	80	53
6	Liquid	12743	260108
7	Area	22000	35000

Source: Commissioner of Statistics, Chennai, Tamil Nadu Economic Appraisal 1993-94.

## Appendix II

### The Corrected Ordinary Least Squares Method

The COLS estimates are easier to compute than that of MLE although they are asymptotically less efficient. The corrected ordinary least square estimators are similar to the estimators suggested by Richmond (1974) in the context of pure frontier. Begin with OLS estimator  $\beta^a = (x' x)^{-1} x' y$ , except for the constant term, the OLS estimator is unbiased and consistent. Its covariance matrix  $(x' x)^{-1} \sigma_\epsilon^2$ , where  $\sigma_\epsilon^2$  is the variance of the error term. That is

Variance of  $\sigma_u^2$  and  $\sigma_v^2$  can be estimated consistently  $\mu = (-\sqrt{2/\pi} \quad 1/\sigma_u^{\wedge})$

$$\sigma_u^{\wedge 2} = [ \sqrt{\pi/2} \quad (\pi/\pi-4) \quad \mu_3^{\wedge} ]^{3/4} \quad \text{and} \quad \sigma_v^{\wedge 2} = \mu_2^{\wedge} - (\pi-2/\pi \sigma_u^{\wedge 2})$$

Where  $\mu_2^{\wedge}$  and  $\mu_3^{\wedge}$  are the second and third moments of OLS residuals. Then constant term can be corrected by adding to the OLS estimated constant term the negative of the estimated bias. ie.

$$-2/\sqrt{\pi} \quad 1/\sigma_u^{\wedge}$$

To recapitulate, the COLS estimators of all elements of  $\beta$  except for the constant term is the same as that of OLS estimate.

### Appendix III

#### Stochastic Frontier Production Function-Maximum Likelihood Estimation

##### Procedure

The ML estimators of  $\theta$ , Maximising the Likelihood Function

$$\ln L(y, \theta) = -n/2 \ln \pi/2 - n/2 \ln \sigma^2 + \sum \{ \ln(1-F(z_i)) \} - 1/2 (1-\gamma/\gamma) \sum z_i^2$$

$$\text{Where } z_i = (y_i - \sum x_{ij} \beta_j) [(\gamma/1-\gamma) 1/\sigma^2]^{1/2}$$

are obtained by setting first order partial derivatives with respect to  $\beta$ ,  $\sigma^2$  and  $\gamma$  equal to zero, that is

$$\partial L/\partial \beta = 0, \partial L/\partial \sigma^2 = 0 \text{ and } \partial L/\partial \gamma = 0 \text{ and}$$

solving them simultaneously

$$\frac{\partial L}{\partial \beta} = -\sum_{i=1}^n \left[ \frac{1}{1-F(z_i)} \right] \frac{\partial F(z_i)}{\partial z_i} \cdot \frac{\partial z_i}{\partial \beta} \cdot \frac{1-\gamma}{\gamma} \cdot 2 \sum z_i \frac{\partial z_i}{\partial \beta} = 0$$

$$\text{and } \frac{\partial F(z_i)}{\partial z_i} = \frac{1}{\sqrt{2\pi}} \exp(-z_i^2)$$

$$\frac{\partial z_i}{\partial \beta} = -x_{ij}' [ \gamma/1-\gamma \cdot 1/\sigma^2 ]^{1/2}$$

$$\frac{\partial L}{\partial \sigma^2} = \frac{n}{2\sigma^2} + \sum_{i=1}^n \frac{1}{1-F(z_i)} \frac{\partial F}{\partial z_i} \frac{\partial z_i}{\partial \sigma^2} \cdot 2 \left( \frac{1-\gamma}{\gamma} \right) \cdot 2 \sum z_i \frac{\partial z_i}{\partial \sigma^2} = 0 \quad \text{---2}$$

$$\frac{\partial z_i}{\partial \sigma^2} = -\frac{1}{2} \left( \frac{z_i}{\sigma^2} \right)$$

and

$$\frac{\partial L}{\partial \sigma^2} = - \sum_{i=1}^n \frac{1}{1-F(z_i)} \frac{\partial F}{\partial z_i} \frac{\partial z_i}{\partial \gamma} + \frac{1}{2\gamma} \sum z_i^2 - \frac{1}{2} \left( \frac{1-\gamma}{\gamma} \right) \cdot 2 \sum z_i \frac{\partial z_i}{\partial \gamma} = 0 \quad (3)$$

Where 
$$\frac{\partial z_i}{\partial \gamma} = - \frac{z_i}{2\gamma(1-\gamma)}$$

In practice it is very difficult to solve the equations defined by (1), (2) and (3). to obtain the ML estimators. This can be done by approximated numerical methods. Newton- Raphson technique is most appropriate for this. But Kale (1962), to reduce over shooting (whether successive estimators overshoot the true solution or not) suggested technique. Which involves controlling the measurement of the successive estimators from the initiated estimator through a predetermined specified proportion of change. The modified Newton Raphson estimator is

$$\theta_1 = \theta_0 - \alpha \frac{\frac{\partial^2 L(y, \theta_0)}{\partial \theta, \partial \theta}}{\frac{\partial L(y, \theta_0)}{\partial \theta}}$$

Where  $\frac{\partial L}{\partial \theta}$  and  $\frac{\partial^2 L}{\partial \theta, \partial \theta}$  are the first and second order partial derivatives of the likelihood function evaluated at the initial parameters  $\theta_0$  represents the specified proportion of change and varies from 0 to 1

Selecting the initial estimate in the neighbourhood of the maximum of the function may be done in the following way (Kalirajan 1982). It is reasonable to expect the estimation of the frontier function to be as high as the OLS estimates of the production function showing average technology. So the initial estimator  $\theta_0$  is assumed to have respectively  $\beta_0$ ,  $\beta_i$ 's and  $\sigma^2$  as the OLS estimate showing the intercept ( $\beta_0$ ) and other parameters ( $\beta_i$ 's) and residual variance. Thus OLS estimators serve as lower bound for the ML estimators. The only value which cannot be taken from OLS estimate is  $\gamma$  and so, different values ranging from 0.1 to 0.9 are tried in the iteration technique (Kalirajan 1992). Iterations are carried out to achieve the maximum value and the estimators associated with that maximum value of the likelihood function in the ML estimate that is the parameter of the frontier function.

## Appendix IV

### Probabilistic frontier Production Function

The Cobb Douglas Production function can be written as

$$y_i = x_{i0} + w_i \quad \text{---(1)}$$

Where the first column  $x_{i0}$  is a vector of ones to allow for an intercept.

If  $w_i$ 's are constraint to one side of the estimated surface that is  $w$  as  $u$  ( $u < 0$ ) the resulting function is an envelope ie. either frontier or anti frontier function to be an efficient. The frontier equation (1) should be estimated.

$$\sum_{j=0}^k \beta_j x_{ij} = y_i > y_i \quad \text{...(2)}$$

Only efficient farms satisfy final equality others have lesser yield than maximum feasible yield. An infinite number of  $\beta$ 's will satisfy equation(2). To find the estimated surface to as closely as possible to the observed set of points, a minimising constraint must be placed on the surface function of the resulting error terms.

Minimising  $\sum_{i=0}^n u_i^2$  would be the most convenient for making comparison with average functions. The quadratic constraints accentuates extreme observations, an undesirable feature when working with envelopes. The alternative to minimise the linear sum of the errors, that is  $\sum_{i=0}^n u_i$  the extreme observations are not unduly weighted in this way. By setting  $u_i \geq 0$ , the equation (2) can be written as an equality

$$\sum_{j=0}^k \beta_j x_{ij} - u_i = y_i \quad \text{---(3)}$$

The estimation technique, then is to minimise

$$\text{Min } \sum_{I=1}^n u_i \text{ subject to } = \sum_{j=0}^k \beta_j x_{ij} > y_i \text{ and } \beta_j > 0$$

in order to solve this by linear programming, it must be expressed as the function of

$\beta_j$  and  $x_{ij}$ . Then summing the equation (3) over all  $i$ 's and there for  $\sum x_i$

$$\sum_{i=1}^n \sum_{j=0}^k \beta_j x_{ij} - \sum_{i=1}^n u_i = \sum_{i=1}^n y_i$$

$$\sum_{i=1}^n \sum_{j=0}^k \beta_j x_{ij} - \sum_{i=1}^n y_i = \sum_{i=1}^n u_i \quad \text{----(4)}$$

For any particular set -  $\sum_{i=1}^n y_i$  - is a constant. Any set of  $b_i$  that minimise for one value will minimise for any other value, including zero. Hence the term -  $(\sum y_i)$  can be dropped from equation (4) with no consequence. The remainder is suitable as linear programming objective function, although for computational purpose it is desirable to divide by  $n$ , the number of observations. Thus the arithmetic mean of the observations on the  $i^{\text{th}}$  input  $x_{ij}$  is used instead of total, then we have,

$$\min u = \hat{\beta}_0 x_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \dots + \hat{\beta}_k x_k \quad \text{-----(5)}$$

subject to

$$\begin{aligned} \hat{\beta}_0 x_{10} + \hat{\beta}_1 x_{11} + \dots + \hat{\beta}_k x_{1k} &> y_1 \\ \hat{\beta}_0 x_{20} + \hat{\beta}_1 x_{21} + \dots + \hat{\beta}_k x_{2k} &> y_2 \\ \hat{\beta}_0 x_{n0} + \hat{\beta}_1 x_{n1} + \dots + \hat{\beta}_k x_{nk} &> y_n \end{aligned}$$

and  $\hat{\beta}_i \geq 0$  with  $\sum_{i=0}^k \hat{\beta}_i = 1$

Then  $y_i / \hat{y}_i$  is the index of technical efficiencies which is a separate measure for each term. These measures are averaged to reach a single estimate for each farm. So far, the discussion, has been in terms of deterministic frontier. To eliminate the problem of errors in the extreme observations. It is desirable to fit probabilistic frontier. The equation (2) may be translated to a probabilistic statement of the form.

$$\text{Prob} \left( \sum_{j=0}^k \hat{\beta}_j x_{ij} > y_i \right) > P, \text{ where } P \text{ is an externally specified probability.}$$

To estimate problem in(5) taking all the farms and determine the 100 percent efficient farms. There will be as many as factors of production with  $\hat{\beta}_i > 0$  having ties. The technique is to discard the first (100-p) percent of the efficient observations until a prespecified level of p is reached. Alternatively efficient observations might be discarded one at a time (or may be more) until the resulting estimated coefficients stabilise. Either way the objective is to estimate a frontier function because of data problems, may be largely over in the function. The production function thus obtained is called the Probabilistic Frontier Production Function.

## Appendix : V

### PROFIT FUNCTION

For a given technology and a given endowment of fixed factors of production, the profit function expressed the maximum profit of farm as function of the prices of output, and variable inputs and the quantity of fixed factors of production (Yotopoulos and Lan 1979)

$$\begin{aligned} \text{Profit} &= \text{Total revenue} - \text{Total cost.} \\ \pi &= P_y f(y) - \sum_{i=1}^n P_i x_i \end{aligned} \quad \dots(1)$$

Where  $\pi$  denotes profit,  $P_y$  and  $P_i$  denote unit prices of output and variable inputs respectively  $f(y)$  is the production function and  $x_i$ 's are variable inputs. The marginal productivity conditions from (1) of a profit maximising farm

$$P_y \frac{\partial f}{\partial x_i} = P_i \quad \text{for } i=1,2,\dots,m \quad \dots(2)$$

$$\frac{\partial f}{\partial x_i} = \frac{P_i}{P_y} = r_i \quad \dots(3)$$

where  $r_i$  means the normalised price of the  $i^{\text{th}}$  variable input.

In (3) there are 'm' equations to solve for m unknowns  $x_i$ 's which yield maximum profit in (1)

$$x_i = f_i(r, z) \quad \text{for } i=1,2,\dots,m \quad \dots(4)$$

where z represents fixed inputs  $x_{m+1}, x_{m+2}, \dots, x_n$

in  $f(y)$  substituting (4) in (1), we get the profit function

$$\pi = p_y f(x_1, x_2, \dots, x_m, x_{m+1}, \dots, x_n) - \sum_{i=1}^m p_i x_i \quad \dots(5)$$

$$\frac{\pi}{p_y} = f(x_1, x_2, \dots, x_m, x_{m+1}, \dots, x_n) - r_i x_i \quad \dots(6)$$

$$\text{where } r_i = \frac{p_i}{p_y}$$

In (6) RHS is a function of normalised prices of variable inputs by output prices and fixed factors of production.

$$\pi^* = g(r_1, r_2, \dots, r_m, x_{m+1}, x_{m+2}, \dots, x_n) \quad \dots(7)$$

and is called unit output price profit function (UOP). No attempt has been made to examine theoretically UOP function.

### **Cobb Douglas Production function.**

Cobb Douglas production with decreasing returns to scale may be written as

$$y = A \prod_{i=1}^m x_i^{\beta_i} \prod_{i=m+1}^n z_i^{\alpha_i} \quad \dots(8)$$

Where  $y$  is physical output  $x_i$ 's and  $z_i$ 's are variable and fixed factors of production respectively.

$$\text{Let } w = \sum \beta_i < 1$$

The profit maximising condition is

$$\frac{\partial y}{\partial x_i} = r_i ;$$

$$\frac{\partial y}{\partial x_i} = \beta_i (A \prod_{i=1}^m x_i^{\beta_i} \prod_{i=m+1}^n z_i^{\alpha_i})$$

$$r_i x_i = \beta_i y$$

$$x_i = \frac{\beta_i}{r_i} y_i \quad \dots(9)$$

substituting the value of  $x_i$  in (8)

$$y = A \prod_{i=1}^m ((\beta_i/r_i)y_i)^{\beta_i} \prod_{i=m+1}^n z_i^{\alpha_i}$$

$$y = A \prod_{i=1}^m (\beta_i/r_i)^{\beta_i} \pi z_i^{\alpha_i} y_i^{\beta_i + \alpha_i}$$

$$y = A \prod_{i=1}^m (\beta_i/r_i)^{\beta_i} \prod_{i=m+1}^n z_i^{\alpha_i} y^w \quad \text{where } w = \beta_i + \alpha_i$$

$$y^{1-w} = A \prod_{i=1}^m (\beta_i/r_i)^{\beta_i} \prod_{i=m+1}^n z_i^{\alpha_i}$$

$$Y = A^{1/1-w} \prod_{i=1}^m (\beta_i/r_i)^{\beta_i/1-w} \prod_{i=m+1}^n z_i^{\alpha_i/1-w}$$

Now the real profit is defined as

$$\pi^A = y - \sum r_i x_i$$

$$= y - \sum r_i \beta_i / r_i y$$

$$\pi^* = y(1 - w)$$

$$\pi^* = A (1-w)^{-1} \left[ \prod_{i=1}^m (\beta_i / r_i) \right] \left[ \prod_{i=m+1}^n Z_i \right] \alpha_i (1-w)^{-1}$$

$$\pi^* = A (1-w)^{-1} \left[ \prod_{i=1}^m (\beta_i / r_i) \right] \left[ \prod_{i=m+1}^n Z_i \right] \alpha_i (1-w)^{-1}$$

where  $w = \sum \beta_i < 1$

Taking natural logarithm on both sides.

$$\ln \pi^* = \ln A^* + \sum_{i=1}^m \beta_i^* \ln r_i + \sum_{i=1}^m \beta_i^* \ln r_i + \alpha_i^* \ln z_i \quad \dots(10)$$

$$\text{where } A^* = A (1-w)^{-1} \left[ \prod_{i=1}^m \beta_i (1-w)^{-1} \right]$$

$$\beta_i^* = -\beta_i (1-w)^{-1} < 0 \quad i=1,2,\dots,m$$

$$\pi_i^* = -\alpha_i (1-w)^{-1} > 0 \quad i=m+1,\dots,n$$

The variable factor demand functions are given Shephard's lemma as

$$x_i^* = \frac{\partial \pi_i^*}{\partial r_i^*} \quad \text{for } i=1,2,\dots,m \quad \dots(11)$$

multiply both sides by  $\frac{r_i}{\pi^*}$

$$\frac{r_i x_i}{\pi^*} = \frac{\partial \ln \pi^*}{\partial \ln r_i} \quad i=1,2,\dots,m \quad \dots(12)$$

in the context of the Cobb Douglas production function (10) becomes

$$\frac{-\Gamma_i X_i}{\pi} = \beta_i^* \quad i=1,2, \dots, m \quad (13)$$

Now the estimation of the empirical profit and factor demand functions can be carried out by estimating (10) and (13) since  $\beta_i^*$  appears in both (10) and (13) these two function should be estimated jointly by imposing the condition that  $\beta_i^*$  are equal in both equation. The restricted Aitken estimation proposed by Zellner (1962) can be employed to estimate the parameter of (10) and (13) jointly. Our approach of estimation to find out which of the equality restrictions of  $\beta_i$  is not valid (Kalirajan 1981)