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पत्र में व्यक्त अभिमत केवल लेखक के हैं, आवश्यक नहीं कि नाबार्ड या आईजीआईडीआर, मुम्बई, आईआईएम बेंगलूर या एनसीएईआर, नई दिल्ली के भी वही अभिमत हों.
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कार्यपालक-सार

इस अध्ययन का मुख्य उद्देश्य यह पता लगाना था कि क्या जोत भूमि की चकबन्दी करना लाभदायक था और यदि था, तो कम से कम खेतीवाली जोतों की चकबन्दी के लिए मार्केट मैकेनिज़्म के काम न करने के क्या कारण रहे. यह अध्ययन निम्नलिखित परिकल्पना की अनुभवजन्य जाँच का प्रयास है.

- जोत के आकार की कोई मानक आर्थिकी नहीं है, अर्थात जोत के आकार और उपज के बीच कोई कार्य-कारण संबंध नहीं है.
- जोत विभाजन की भी कोई मानक आर्थिकी नहीं है, अर्थात उपज और जोत विभाजन के बीच भी कोई कार्य-कारण संबंध नहीं है.
- यदि किसान जोत-विभाजन स्तर का चयन कर सकते हैं तो विभाजन का जो वर्तमान स्तर है, वह सर्वाधिक अनुकूल है. बाजार की कुछ विफलताएं है, जिनसे चकबन्दी बाधित होती है.
- तमिलनाडु में नागपट्टिनम जिले के नेलपत्तूर गाँव के १८६ किसानों से संबंधित पाँच वर्षों की अवधि (१९९५-९९) के आँकडे एकत्र किये गए. मुख्यतः फसलों, प्राप्तियों (आउटपुट), निविष्टियों (इनपुट) और उत्पादन के स्थायी कारकों के स्वामित्व से सम्बन्धित आँकडे एकत्र किये गए प्रत्येक किसान के मामले में, उसकी मिल्कियत वाले अलग-अलग प्लाटों के क्षेत्रफल और प्रत्येक प्लॉट में उगाई गई फसलों के बारे में आँकडे जुटाए गए. जहाँ तक प्राप्ति से संबंधित आँकडो का सम्बन्ध था, उसके लिए किसान द्वारा उगाई फसल की उपज, बेची गई उपज की मात्रा और प्राप्त आय सम्बन्धी आँकडे लिये गए. उक्त अध्ययन के लिए कपास और कुरुवाई की एकल फसल के साथ-साथ दो मुख्य आगे-पीछे ली जानेवाली फसलों के समूहों अर्थात खरीफ साँबा-कालाचना और साँबा-कपास को चुना गया. उक्त परिकल्पनाओं के परीक्षण हेतु अर्थमिति की विभिन्न पद्धतियों का प्रयोग किया गया.

उक्त अध्ययन से ज्ञात हुआ कि नेलपत्तूर गाँव के २०% किसानों के पास पाँच से ज्यादा भूखण्डों के मालिक थे, जबकि ४०% किसान तीन से पाँच भूखण्डों के मालिक थे. शेष किसानों के पास तीन से कम भूखण्ड थे. अध्ययन से यह भी पता चला कि छोटे फार्मों में विभाजन महत्वपूर्ण रुप से असर डालता हैं.

उपर्युक्त अध्ययन के प्रमुख निष्कर्ष निम्नानुसार थेः

- फार्मों के टुकड़ों में बँटे होने का काला चना और कपास आदि जैसी महत्वपूर्ण क्रमिक फसलों के मामले में तकनीकी दक्षता और उत्पादन पर प्रतिकूल प्रभाव पड़ता हैं.
- तथापि, कपास, कुरुवाई या कालेचने की स्वतन्त्र रुप से ली गई फसलों के मामले में उक्त प्रभाव महत्वपूर्ण प्रतीत नहीं हुआ.
- अनुकूलतम चकबन्दी की स्थिति में किसानों के पास तीन बराबर-बराबर भूखण्डों से कम टुकड़ों में भूखण्ड होंगें और अधिकतर मामलों में चकबन्दी इससे अधिक होंगी.
- कम विभाजित जोतों पर कुरुवाई की खेती करनेवाले किसानों के मामले में तकनीकी कुशलता और आउटपुट उच्चतर स्तर का था. यह तथ्य कपास की खेती करने वाले किसानों के मामले में भी सही पाया गया. इस प्रकार, अध्ययन से पता चला कि तकनीकी कुशलता बढ़ाने में फार्मों के आकार की महत्वपूर्ण भूमिका होती है.
- तकनीकी दक्षता के हिसाब से चकबन्दी ज्यादा लाभदायक पाई गई.
- तथापि, उक्त अध्यन इस बात का हल निकालने की दृष्टि से अपूर्ण रहा कि मार्केट किसानों को इसके लिए क्यों नही प्रेरित कर पाते है कि वे स्वयं, कम से कम उन जोतों की चकबन्दी कर ले जिनमें वे खेती कर रहे है.

EXECUTIVE SUMMARY

The main objective of the study was to explore whether consolidation of land holdings was beneficial and if so, reasons for market mechanism not working to consolidate at least the operational holdings. The study makes an attempt to test empirically the following hypotheses:

- There are no economies of scale with respect to farm size i.e., yield is NOT a function of farm size.
- There are NO economies of scale with respect to fragmentation i.e., yield is NOT a function of fragmentation.
- If farmers can choose the level of fragmentation, the present level of fragmentation is optimal.
- There are market failures that obstruct consolidation.

Data were collected for a period of five years (1995-99) from Nelpathur village of Nagapattinam district in Tamil Nadu covering 186 farmers. The data were mainly collected on crops grown, output, input and ownership of factors of production. For each farmer, the data were collected on the acreage of various plots owned by him and the crops grown in each of these plots. As far as output data was concerned, yield of crops grown by a farmer, quantity sold and revenue made was collected. The study covered two major crop sequences i.e. Samba-Blackgram and Samba-Cotton along with single crop of cotton and Kuruvai. To test the hypotheses, various econometric methods were used.

The study observed that in Nelpathur village, 20% of the farmers owned more than five plots while 40% owned between three and five plots and the remaining had less than three plots. The study also observed that fragmentation is significant in small farms.

The major findings of the study were as under:

- Fragmentation has an adverse impact on technical efficiency and in the production of most of the important crop sequences like blackgram and cotton, etc.
- The impact however did not seem to be significant in the case of cotton, *kuruvai* or blackgram when taken independently.

- Optimal consolidation would lead to farmers having equivalent of less than three equal plots and mostly much more consolidation than that.
- Higher levels of technical efficiency and output were found in the case of farmers cultivating *kuruvai* on less fragmented holdings. This was true also for farmers cultivating cotton crop. Thus, the study observed that the farm size played a significant role in promoting technical efficiency.
- The gains in terms of technical efficiency were also large from consolidation.
- The study however remains inconclusive in resolving why markets do not induce farmers on their own to consolidate at least their operational holdings?

CHAPTER 1

PERSISTENCE OF LAND FRAGMENTATION : SOME HYPOTHESES

1.1 Introduction

The Problem

Fragmentation of land is widespread in the country. Even the very small land holding of an average farmer is split into many smaller fragments. Fragmentation has some obvious disadvantages. A farmer cannot visit all his fragments everyday without wasting much time in travelling. There is also loss in plot borders, hedging, etc. Use of mechanical devices becomes difficult, and so on.

In fact, many agricultural economists and agronomists recommend consolidation as an important precondition for agricultural development.

A question then arises. If consolidation is so beneficial, why does not it happen by itself? Why does not market mechanism work to consolidate at least operational holdings?

We need to first test empirically the premises underlying the general belief of agricultural economists and agronomists. If we assume that farmers are rational, then they must not see any gains from consolidation. For this to be true, we advance the following hypotheses.

Hypotheses

1. There are no economics of scale w.r.t farm size i.e. Yield is NOT a function of farm size.
2. There are NO economies of scale w.r.t fragmentation, i.e. yield is NOT a function of fragmentation.
3. If farmers can choose the level of fragmentation, the present level of fragmentation is optimal.
4. There are market failures that obstruct consolidation.

The Objective of Research and its Relevance for Policy

We want to test these hypotheses. If the first three hypotheses hold true, then fragmentation is a non-issue and consolidation is a waste of social energy. If on the other hand, the first three hypotheses are not held, we would quantify the gains from consolidation. This would be valuable in deciding the importance of it. In either case, the project would produce results of considerable policy significance.

1.2 The Background

In developing economies in Asia such as India, in Africa such as Zimbabwe, and in South America and Latin America like Brazil and Mexico respectively, land reform legislations have occupied a central role in poverty alleviation programmes. Improvement in the distribution of land holdings has been viewed as an important element of the policy to reduce chronic poverty (Chenery *et al* 1970). However some of the side effects of land reforms have been - a) reduction in the farm size, and b) fragmented pattern of holdings of land. In the context of globalisation, questions have been raised regarding productivity and sustainability of agriculture. It is believed that land fragmentation would lead to less than optimal crop choice and sub-optimal usage of factor inputs i.e. technically inefficient usage, all of which would lead to less than sustainable incomes for farmers and a resultant rise in all poverty estimates. Using primary data, we propose to examine in this paper, the relationship between land fragmentation, crop choice and technical efficiency of the farmers in the tail end of the Kaveri delta.

Agriculture in most economies has been a byproduct of river valleys. This is true of both developed and developing economies such as Mississippi valley in the United States, and the Gangetic plains in India. River valley agriculture gives ways to several problems relating to human settlement, sustainability of usage of resources, and susceptibility to elements of nature such as floods, etc. One of the characteristics of river valley agriculture in most parts of the world and particularly in developing countries is a startling difference in population pressures on land. The basin areas are typically sparsely populated while the middle and tail ends have very high population density. This phenomenon is prevalent along with similar differences in the quality of land. Another phenomenon in the river valley systems is the differences in both the size of land holdings and in the size of plots. In India, with the onset of colonial rule, the Zamindari system arose in many of the river valleys.The Zamindari system was characterised by highly inequitable pattern of land holdings with very few land owners holding onto most of the cultivatable land. One of the categories of land reforms was connected with efforts to implement ceilings on land holdings and redistribute surplus land to the landless.

The consequence of this has been inadvertently, reduced size of land holdings and fragmentation of land holdings by farmers.

Given that land reform measures have reduced the size of land holdings, discussions on the impact of land reforms have been dominated by the observed inverse farm size and productivity relationships where small farmers are able to use resources more efficiently to achieve greater yield (Binswanger *et al* (1995)). Others have found that this relationship is ambiguous (Banerjee and Ghatak (1996)). The impact of fragmentation on yield and productivity has been examined by Carlyle (1983), Heston and Kumar (1983), Bentley (1987), Blarel *et al* (1992), Jabarin and Epplin (1994). The debate has focused basically on the impact of fragmentation on the ability of farmers to minimise risk. One aspect of the land reforms has been to create incentives to farmers to consolidate their land holdings. Therefore it is pertinent that we examine the issue of farm size along with fragmentation and consider its effect on efficiency. It is perceived that the yields of major crops in India are below the international average. For example, the yield of cotton is 1.7 tons per hectare while the international average is close to 4 tons. It is felt that such yield gaps are a result of fragmented land holdings leading to technically inefficient usage of resources.

It is important that any policy decision must be based on the clear understanding of factors affecting efficiency of cultivation. In this chapter, we estimate the technical efficiency of farmers growing *kuruvai, samba*, blackgram and cotton using a stochastic production function. By isolating the contribution of different factors determining inefficiency, we can assess the role of fragmentation. Of primary importance is the importance of the role played by fragmentation in influencing the technical efficiency.

The process of cultivation will be influenced both by factors specific to farms and those that are exogenous. The former include factors such as fragmentation, farm size, ownership of machinery and bullocks, wage gap, hired labour and time. The latter include volatility in output prices, government policies, etc.

The technical efficiency of a farm is a measure of the farms' ability to produce maximum output with a given set of inputs and technology (Green 1980). Measurement of farm efficiency can provide useful insights into the competitiveness of farms and their potential for raising productivity and improving resource use. In recent years, there has been an increase in literature concerned with assessing the technical efficiencies of farms. Empirical evidence suggests that farmers in developing agriculture fail to exploit the potential of technology with the result showing wide variation in yields associated with variations in management capacity of the farmers in input usage. For example, various studies carried out in the Philippines (Herdt and Mandac, (1981), Kalirajan and Flinn(1983), Dawson and Linagard (1989) find 25-50% inefficiency in rice production, and a positive relationship between efficiency and various management variables. Taylor and Shonkwiler (1986) and Shapiro (1983) estimated technical inefficiency to be as high as 30% in Brazilian agriculture and 34% in Tanzanian agriculture. Ali and Chaudhry (1989) concluded that the profit of farmers in Punjab of Pakistan could be increased by 28% through improved efficiency, which is positively related with education and timeliness of input usage. In the Indian agriculture since the 1970's, efficiency measures have been estimated. Some examples are Huang and Bagi (1984), Kalirajan (1981), Junankar (1980), Sidhu (1974), Lau and Yotopoulos (1971), Battese, Coelli and Colby (1989), Tadesse and Krishnamoorthy (1997), Kumbhakar and Bhattacharya (1992), and Jha and Rhodes (1999). Most of these studies, applying the techniques of stochastic production frontiers, find that the large variation in yield is due to difference in technical efficiency, which is largely influenced by variation in farm size, size of the land holding, ecological factors and their interactions with factor inputs like land, technology and fertiliser. This chapter uses stochastic production frontier technique to estimate the technical efficiency levels of farms growing various crops in order to explain the farm specific effects leading to technical inefficiency in crop cultivation in the tail end of the Kaveri delta. The estimation involves a simultaneous estimation of the parameters of the production function and technical inefficiency effects and uses a panel data of farms spanning over time period of five years (1995-99). Of primary importance, in this chapter is the role of the fragmentation of the land holding in influencing efficiency, technical change and its impact on the ability of farmers to effectively manage the input usage.

In this paper we wish to examine, the impact of fragmentation on technical efficiency when, (a) a single crop is grown, and (b) a crop sequence is chosen by the farmers.

A related question is as follows: If fragmentation reduces technical efficiency and if farmers can select the level of fragmentation, what is the optimal level of fragmentation? Optimal will be determined as the fragmentation that maximizes technical efficiency, i.e. maximum output for a given level of inputs.

1.3 The Approach

We have collected complete data on all fragments in a village for all households. This data set is a unique data set. We are able to describe for each cultivating household

- The number of fragments he holds
- The area of each fragment
- The location of each fragment on the map
- The location of house
- The crops grown over the last five years in each fragment
- The yields obtained from each fragment
- The cost of cultivation for each crop on each fragment
- The quality attributes of each fragment in terms of

  - Access to irrigation

  - Quality of irrigation source

  - Maximum (agronomic) yield of different crops from that fragment

These data along with data on the variability of yields and prices in that district will provide adequate information to test the first three hypotheses.

1.4 The Data Collected

Data from Nelpathur village was collected through questionnaires administered to farmers. Data was collected for all the 186 farmers within the village, for a period of 5 years ranging between 1995-99. Data was collected under the different headings of land holdings, crops grown, output, input and ownership of factors of production. For each farmer, data was collected on the acreage of various plots owned by him, and the crops grown in each of these plots. Under output data, output of crops grown by a farmer, amount sold and revenue made was collected. Farm input data was collected in terms of total cost spent on seeds, fertilisers, irrigation, bullocks, cartage, manure and machinery. The value of the family provided inputs was also collected. Such data was collected for each crop. However, due to multi-collinearity problems, we added the purchased and family provided parts of these inputs while using the data for analysis. Data was also collected regarding ownership of certain factor inputs like bullock, cartage, farm machinery, filter point, oil engine, *etc.*, by a farmer.

From the data collected it is seen that in Nelpathur, 20% of the farmers own more than 5 plots, while 40% own 3-5 plots and the remaining farmers have less than 3 plots. It is also seen that from the 60% of farmers who own less than 3 acres of land (small farmers), 35% of this group owns between 3-5 plots, 25% of this group owns 5-10 plots and the balance owns less than 3 plots, thereby showing that fragmentation is significant in small farms.

1.5 Village Setting

For the purpose of this analysis we have chosen Nelpathur village located at the tail end of the Kaveri River in the state of Tamil Nadu in peninsular India. Nelpathur village has a total cultivable land of 1000 acres. The current number of active cultivators is 186, cultivating a total of 950 acres. Nelpathur is typical of any tail end village of the river valley in that two extreme forces impact it, one being scarcity of water, and the other being floods, during the different periods of the cultivating seasons. Prior to the land reform acts of 1950's and 60's, the cultivation in the village was controlled by 6 major landowners. The primary crop in the village was rice, comprising of two varieties, one of medium duration, and the other of longer duration called "samba". The crop choice widened post 1960s after the introduction of electrified filter points (bore wells). This coincided with the discovery of several High Yielding Varieties of rice by the IRRI (International Rice Research Institute). The village started seeing three crops of rice grown. In the seventies, the cultivation of rice decreased, and sugarcane was introduced on a fairly large scale. For example in the seventies, close to 300 acres of sugarcane was planted.

The river Kaveri flows through two states viz., Karnataka and Tamil Nadu. This is a non-perennial river prone to floods during the North-East and South-West monsoons (period of June to November). In the eighties (1981-1991) there was a dispute over water sharing between Tamil Nadu and Karnataka. Tamil Nadu being a lower riparian state has received infrequent amounts of water that affected availability of water throughout the delta. The reaction to this was crop diversification by the farmers of the tail end. For example, between 1986-1991, the acreage under the first short-term rice crop *(kuruvai)* came down from 250 acres to 55 acres. The number of rice crops was reduced to 2, viz., *kuruvai and samba.* The acreage under Blackgram went up sharply. The crop is treated as a secondary crop with inconsequential input costs. The crop is cultivated just after *samba*, between January and April. So acreage under black gram went up sharply by nearly 170%. Cotton was introduced in the mid-seventies in this area by one of the larger farmers in the village. Its acreage has increased from 30 acres in 1983-84 to 160 acres in 1996-97. In fact for the period that this survey was conducted (1992-93 to 1996-97) acreage nearly doubled. There are other crops like groundnut, which were grown, but due to extreme problems like price volatility, increased prices of groundnut seeds, etc., acreage under groundnut cultivation has also come down. Sugarcane cultivation in the village has come to a near standstill due to governmental policies regarding the number of sugar mills in the vicinity and their respective capacities.

Another problem that tail end villages face is the ability to use the subsoil water for irrigation. Due to the vagaries of the flow of the river, the level of the water table has receded from 16 feet in 1995-96 to 45 feet by 1999-2000. Consequently a number of these filter points have been lost, and farmers are forced to cultivate in areas otherwise unfit for cultivation. In Nelpathur alone 200 cultivable areas have been lost to salinity.

1.6 Plan of the Report

This report then describes the broad characteristics of agriculture in the village. Chapter 2 gives the methodology for testing the hypothesis. Chapter 3 presents the results of econometric analysis and concludes.

CHAPTER 2

METHODOLOGY

2.1 Technical Efficiency and Its Determinants : Model specification

Since the seminal work of Farrel (1957), the measurement of technical efficiency of production of decision making units (DMU) has become a commonplace for researchers in productivity analysis, with the development of parametric and non-parametric approaches, viz. the stochastic frontier and data envelopment analysis (DEA) respectively (See Box 1). While the strength of DEA is non-parametric and the fact that we do not need to assume a production function, the stochastic frontier allows for hypothesis testing and construction of confidence intervals. The stochastic frontier also allows for the estimation of the impact of the determinants of inefficiency apart from the factors of production.[1] The literature on this approach has seen significant change from being deterministic, where all deviations from the frontier are attributed to inefficiency, to stochastic, where the deviations are from normal random errors and inefficiency factors.

One of the earliest parametric methods of estimating technical efficiencies of DMUs is of Aigner and Chu (1969). The estimation model based on the assumption of a Cobb-Douglas production function is deterministic and is of the following types.

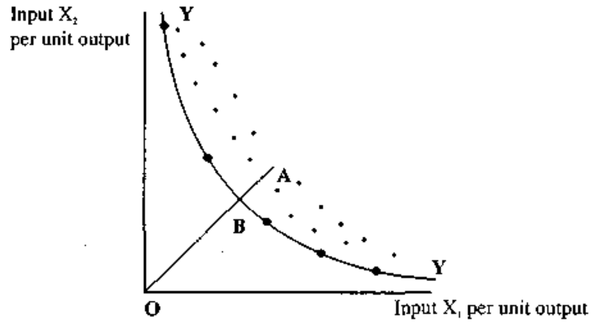
$$\ln(y_i) = x_i\beta + u_i \qquad (1)$$

where ln (y_i) is the logarithm of the output for the i^{th} farm, x_i is a (K+1)-row vector, whose first element is "1" and the remaining elements are the logarithms of the K-input quantities used by the i^{th} farm. β is a (K+1) column vector of unknown paramenters to be estimated; and u_i is a non-negative random variable, associated with technical efficiency in production of farms. The model is estimated by minimizing the sum of the u_i's using linear programming method. Afriate (1972) estimates a similar model using a maximum likelihood (henceforth ML) method where u_i are assumed to follow a gamma distribution. Richmond (1974) uses an alternative method called COLS (corrected

[1] Wadud and White (2002) mention that DEA has the advantage of allowing multiple outputs. But there are techniques for allowing multiple outputs in the stochastic frontier too. See Coelli and Perleman (2000), Seaz adn Pozo (2001), and Whiteman (1999).

Box1: Frontier Production Function and Technical Efficiency

If we compare a large number of farmers who use the same two inputs X_1 and X_2, for example, and produce the same output, we can plot these as follows:



We can take the extreme points shown boldly, close to the origin and draw an envelop that will show an isoquant. The farms on this isoquant are technically the most efficient farms. Other farms use more of one or more inputs to produce the same one unit of output. The isoquant YY thus represents the frontier production function. We can define the technical efficiency of any point A by the ratio of the ray from the origin OB/OA.

We have assumed that the points in the diagram have no measurement errors. If we stipulate random errors of measurement then the efficient isoquant would be different. This gives the stochastic frontier production function used in this study.

measures of OLS) where the biased estimate of the intercept term β_0 is adjusted using the sample moments of OLS residuals.

One main criticism of the above model is that any possible impact of measurement errors or noise upon the frontier has not been considered. Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) independently attempted to rectify this problem by considering another random error into model. The model therefore is known as stochastic frontier production function. This can be described as

$$\ln(y_i) = x_i\beta + (v_i - u_i) \qquad (2)$$

where v_i are iid N $(0,\sigma_v^2)$ and independent of u_i's which are non-negative random variables assumed to account for technical inefficiency in production (are often assumed to be iid $N(0,\sigma_u^2)$. The advantage of the model is that it allows for the testing of hypotheses using traditional ML methods. On the other hand, one main problem of this model is that there is no justification of the *a priori* selection of the distribution of u_i. Aigner, Lovell, and Schmidt (1977) estimate the model with the log likelihood function expressed in terms of the two variance paramenters,$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$ and $\lambda = \sigma_u / \sigma_v$. Battese and Corra (1977) suggest that the parameter $\gamma = \sigma_u^2 / \sigma_s^2$ be used so that it has a value between zero and one. The estimate of β, σ_s^2 and γ obtained by maximum likelihood estimatation are consistent and asymptotically efficient. The null hypothesis for no technical inefficiency effects in the model (2) of Battes and Corra (1977) is $H_0 : \gamma = 0$ with the alternative $H_1 : \gamma > 0$. Since γ cannot take negative values, Coelli (1995) suggested that a one sided generalized likelihood-ratio test should be performed.

A number of functional forms have been used in the literature. In the early part of the literature, Cobb-Douglas functional form was often used because of its simplicity as its logarithmic transformation provides a linear model. However, it is associated with many restrictive properties like constant input elasticities, constant returns to scale and perfect elasticity of substitution between the factor inputs. The translog functional form is another alternative flexible form that is frequently used. The main advantage of the translog form lies in the fact that it does not impose any restrictions like perfect elasticity of substitution.

Another important advantage of model (2) is that we can accommodate time varying cross-sectional data, i.e. panel data. Using panel data not only allows a larger degree of freedom but also simultaneous investigation of both technical efficiency change and technological change over time is possible[2]. Kumbhakar (1990) suggests a stochasitc frontier model for panel data, in which the technical inefficiency effects vary systematically with time, according to the time-varying specification, $u_{it} = [1 + \exp(bt + ct^2)]^{-1} u_i$, where the u_i's are assumed to be half-normal distribution and b and c are unknown parameters to be estimated. Battese and Coelli (1992) suggest an alternative to this for panel data estimation where, the technical inefficiency $u_{it} = \{\exp[-\eta(t-T)]\} u_i, i = 1,..N, t = 1,....,T$ where η is an unknown parameter to be estimated. One of the advantages of this model is that the technical inefficiency changes over time can be distinguished from technical change, provided the latter is properly specified in the vector x_{it} within the frontier function. Empirical studies using balanced panels can be

[2] Technical change (TC) is the shift in the production function (e.g. could be because of an innovation in technology) while technical efficiency change (TEC) is the change of the relative positions of the farm from the same frontier i.e. same technology (e.g. could be because of the change in the nature of the input usage). The simultaneous investigation in these is important because the change in output of a farm over time is to be analyzed to see if it is a result of a) TC, b) TEC or c) both simultaneously.

found in Pitt and Lee (1981), Schmidt and Sickles (1984), Battese and Coelli (1993, 1995), Cornwell, Schmidt and Sickles (1990), Kumbakar and Hjamarsson (1993), Jha and Rhodes (1998), Piesse and Thirtle (2000) etc.[3] These models have further been extended by Battese, Coelli, and Colby (1989), Seale (1990) and Ahmed and Bravo-Ureta (1996), to take care of unabalanced panel data structures.

A very important development to model (2) is the step towards finding the determinants of technical inefficiencies among farms. Huang and Liu (1994) present a model for a stochastic frontier production function, in which technical inefficiency effects are specified as a function of farm-specific factors, together with their interactions with the input variables of the frontier function. Battese and Coelli (1995) estimated the parameters of the factors believed to influence the levels of the technical inefficiency effects, together with the separate components of technical inefficiency change and technical change over time. This can be specified as follows,

$$u_{it} = z_{it}\delta \qquad (3)$$

where z_{it} is a (1xM) vector of observable explanatory variables, whose values are constants; and δ is a (1xM) vector of unknown scalar parameters to be estimated. This model specification also encompasses a number of other model specifications as special cases. If we set $T=1$ and z_{it} contains the value one and no other variables (i.e. only a constant term), then the model reduces to the truncated normal specification.

Thus, the general frontier model incorporating all the recent developments can be expressed as follows:

$$Y_{it} = f(x_{it}, t, \beta) + v_{it} - u_{it}, \; i=1,2,\ldots, N, \; t=1,2, \ldots\ldots T,$$

where Y_{it} is (the logarithm of) the production of the i^{th} firm in the t^{th} time period;

x_{it} is a kx1 vector of (transformations of the) input quantities of the i^{th} firm in the t^{th} time period;

$f(.)$ is a suitable functional form,

[3] Cornewell, Schmidt and Sickles (1990), Kumbhakar and Hjalmarsson (1993) estimated the time-varying technical inefficiency in a two way process where the residuals from the first stage are regressed on the supposed determinants of inefficiency. Battes and Coelli (1993), Jha and Rhodes (1998) and Piesse and Thirtle supposed determinants of inefficiency along with their interaction with the factors of productions in one stage only.

β is a vector of unknown parameters to be estimated;

t is a time trend representing technical change;

the υ_i's are random variables, which are assumed to be iid. $N(0,\sigma_\upsilon^2)$, and independent of the u_i's which are non-negative random variables, iid $N(0,\sigma_U^2)$, assumed to account for technical ineficiency in the production. The technical inefficiency is given by

$EFF_i = E(Y_i^*\backslash u_i, x_i)/E(Y_i^*\backslash u_i = 0, x_i) = \exp(-u_i)$, *where* Y_i^* is $\exp(Y_i)$ and this value lies between zero and 1. It is equal to 1, when it is fully efficient. For our purpose of the estimation of the technical efficiency of the cultivation of crops in the tail end of the Kaveri delta, we follow the general model of the stochastic frontier where we use a flexible translog function.

$$Y_{it} = \beta_o + \sum_{j=1}^{7} \beta_i \ln x_{ijt} + \frac{1}{2}\sum_{j=1}^{7}\sum_{j=1}^{7} \beta_{jk} \ln x_{ijt} \ln x_{ikt} + \beta_t + \beta_{tt} t^2 + \tau_t f_z + \tau_{tt} f_z^2 + v_{it} - u_{it} \qquad (4)$$

where, for i^{th} firm in t^{th} time period,

Y_{it} is (the logarithm of) the Tornqvist index of the outputs of Kuruvai, samba, Blackgram and Cotton,[4] x_{it} are the independent variable: inputs namely acreage, labor, labor for harvest and threshing, land preparation (labour), fertilizer and manure, bullocks and machinery, and, irrigation.[5]

β's and τ's are unknown parameters to be estimated;

$t = 1,\ldots 5$ is a time trend for the duration of the panel;

$f_z = 0$ to 1 is the Fisher's Fragmentation Index where 0 is a fully

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Balanced panel is the structure of the data where the block of all, say, N individual farms are repeated vertically T time, where T is the length of the times series of the cross sectional data. If data of a farm are not available for a particular time period, then we still include it the panel by considering the respective data points as missing values. If we remove the farm for the particular time period from the panel, then the data sturcture is called unbalanced panel.

[4] If y_i and x_j are the multi-output and multi-input quantities, and w_i, and υ_j are the respective value shares for outputs and inputs, the Tornqvist index is given by

$$\ln Y_{it}^{\tau} = \frac{1}{2} \sum_{j=1}^{N} (w_{is} + w_{it})(\ln y_{it} - \ln y_{it})$$

[5] The labour used is in units.

consolidatd land holding[6]. the υ_i's are random variables, which are assumed to be iid. $N(0,\sigma_\upsilon^2)$,

u_i's are independent of v_i's and are non-negative random variables, iid $N(m_{it},\sigma_u^2)$ assumed to account for technical inefficiency in the production.

In the above model, we have u_i's, which are non-negative unobservable random variables associated with the inefficiency of farm production, such that, given the x_{it} the observed level of output falls short of potential. As we had discussed earlier, there are various models where inefficiency is (a) function of time, (b) function of time and determinants of inefficiency, (c) function of determinants and their interactions with the x_{it} variables etc.

We specify the mean of u_i's i.e. m_{it} as the following function that incorporates the supposed determinants of the inefficiencies.

$$m_{it}=\sum_{j=1}^{N} (\delta_{jz} z_{ijt})+\sum_{j=1}^{7} \delta_{xzj} (z_{ijt} * x_{ijt}) +\sum_{j=1}^{7} \delta_{tj} (x_{ijt} * t)+\sum_{j=1}^{7} \delta_{ttj} (x_{ijt} * t^2)+$$

$$\sum_{j=1}^{7} \tau_{ij} (x_{ijt} * f_z)+\sum_{j=1}^{7} \tau_{ttj} (x_{ijt} * f_z^2)+\delta_t t+\delta_{tt} t + \varepsilon_{it} \qquad 5$$

[6]One minus the Simpson index of diversity (Patil and Taillie (1982)) gives the Fisher's Fragmentation Index. The index f_{zi} (Fisher's Fragmentation Index) is calculated for each farm house i and represents one minus the sum of the squared proportional area of each field. This index f_{zi} is given by

$$f_{zi} = 1-\sum_j (Wij)^2$$

where, $\sum(W_{ij})^2$ (Simpson index of diversity) equals the sum of the square of the proportional area of field j to the total owned land of household, i.e. it is the summation of the square of the area of a plot owned by the farmer relative to the total area owned by that farmer. The f_{zi} measures the degree of fragmentation of a farmer's landholdings. It ranges between 0 and 1, 0 indicating complete consolidation, and 1 representing high levels of fragmentation. The following table gives a feel of the fragmentation index.

No. of equal plots	Fragmentation index
10	0.9
8	0.875
6	0.83
4	0.75
2	0.5

The fragmentation index depends on the number of plots owned and the acreage of the plots. There have been attempts in the past notably by Bhalla and Roy (1988), to examine the impact of variability in soil quality on yield. In the absence of a consistent measure of soil quality, an appropriately constructed fragmentation index would suffice to explain both the impacts of variable soil quality and fragmentation on acreage commitment and crop sequencing. Repeated soil tests were carried out at various places in the village between 1995 and 1997. The results relating to the pH factor were not consistent. Also, using this information in the manner suggested in Bhalla and Roy (1988) proved inconclusive in explaining acreage commitment and the choice of the crop sequence. Hence we have chosen to use the Fisher's fragmentation index for the purpose of estimation.

Where, z_{ijt} are the variables that are supposed to determine the inefficiency factors such as farm specific variables like fragmentation, farm size, ownership of machinery and bullocks, wage gap, hired labor, and time. Wage gap is defined as the difference between the wage paid to the hired agricultural worker and the wage received by the same agricultural worker during off-farm season in brick-kilns and prawn farms. This gap appeared around 1994-95 and has caused the agricultural wages to be raised upwards. In addition to this the viability of the second crop after rice (especially samba) is dependent of the availability of hired labor. The second crop usually is grown when the brick-kilns and the prawn farms are in operation. Hence the labor supply during the period when the second crop is grown is seriously truncated. This has consequences in the form of less then the optimal quantity of labour being available to the farmers growing the second crop. Therefore we believe that the wage gap will impact the technical effieciency of cultivation of various crops and crop sequences. We have basically included both family provided labor and hired labor in the calculation of total labor. But for the purpose of estimating it as a factor contributing to technical inefficiency.

$\delta_{jz}, \delta_{xzj}, \delta_{tj}, \delta_{ttj}, \delta_{t}, \delta_{tt}, \tau_{tj}, \tau_{ttj}$ are the parameters to be estimated. This is a non-neutral stochastic frontier of Huang and Liu (1994).[7]

We use t and t^2 inside the frontier to examine the role of time in influencing technical change. To this extent, technical change is a purely endogenous factor. Time is also used as a factor that could create non-neutrality. This is in line with the logic that with the passage of time, the technology in use could influence the rate of substitution between factors of production.

Fragmentation is used in the same spirit as time inside the frontier. We wish to ask wheather increased fragmentation will affect technical change or not. The magnitude of fragmentation is also used as a factor that could create inefficienncy and non-neutrality.

[7] Non-neutrality means that some of the input factors are intrinsically related with some farms-specific inefficient terms and hence the shift is tilting (non-monotonic) with respect to the factor input – that is, both marginal productivity with respect to the specific inputs and marginal rate of substitution get changed. For example, if (soil quality * log fertilizer) is one of the inefficient terms that has a significant inefficient effect on the production function, then the function is non-neutral with respect to soil-quality. If the soil quality change through appropriate use of manure or fertilizer, there could be change in the marginal productivity with respect to fertilizer and the marginal rate of substitution between fertilizer and other input factors.

2.2 Estimation Procedure

The general model of the stochastic frontier(4) along with the technical inefficiency effects (5) can be simultaneously estimated by maximum likelihood method with the null hypothesis for no technical inefficiency effects $H_0 : \gamma = o$. The parameter γ lies between 0 and 1 and this range can be searched to provide a good starting value for use in the iterative maximization process such as Davidson- Fletcher-Powell(DFP) algorithm. We use the FRONTIER 4.1 of Coelli (1996) to estimate the models. If the null hypothesis is accepted this would mean that σ_u^2 is zero and therefore would mean that the u_i's do not have much role. In such a situation Coelli (1996) suggests that an OLS regression will give consistent estimation.

If this is the case, then, we need to test whether a fixed effects/random effects model is preferred over an OLS because of the fact that we are using a panel data. Examples of the early attempts to test this choice are Kuh (1959), Mundlak (1961), Hoch (1962), Balestra and Nerlove (1966) etc. (for the recent developments see Baltagi (2001)). OLS estimation will be misspecified in the presence of farm specific effects. In the following, we describe the econometeric methodology of conducting FEM/REM to test the presence of fixed effects in our model.

The fundamental advantage of a panel data set over cross section is that it permits greater flexibility in modelling differences in behaviour across farms. The essential structure for most of the panel data models is an effects model in which the variation across groups (individuals) or time is captured in simple shifts of the regression - i.e. change in the intercepts. We consider a one-way error component model:

$$Y_{it} = \alpha + X_{it} + v_i + \varepsilon_{it} \qquad (6)$$

when i denotes cross-sections and t dentoes time periods. α is a scalar and β is K x 1 and X_{it} is the i^{th} observation on k explanatory variables. In this model, $v_i + \varepsilon_{it}$ is the residual.

In the fixed effects model, the error term v_i becomes a constant for each group (unit) and thus is unit-specific residual; it differs between unit, but for any particular unit, its value remains same. ε_{it} is the usual residual with the standard properties (Zero mean, no serial correlation or heteroskedasticity, zero correlation with X and v). A classical regression model can handle this with group specific dummies. But it is cumbersome for large N.

The fixed effects model becomes a random effects model if the v_i's are assumed random within each group (unit). But for a given group, the disturbances in different periods are correlated. Therefore it is a generalized regression model.

Independent of the properties of υ_i and ε_i if equation (6) is true, it must be the case that averaging over time will yield

$$\bar{Y}_i = \alpha + X_i \beta + \bar{v}_i + \bar{\varepsilon}_i \qquad (7)$$

where Y,X and ε have been expressed in terms of their means.

Subtracting equation (6) from (7), we have,

$$(Y_{it} - \bar{Y}_i) = (X_{it} - \bar{X}_i)\beta + (\varepsilon_{it} - \bar{\varepsilon}_i) \qquad (8)$$

These three equations provide the basis for estimatingβ.Eqn (8) can be estimated using OLS technique to provide us with fixed -effects estimator - also known as within estimator. Equation (7) can be estimated using the OLS technique to provide the between estimator. The random effects estimator is a weighted average of the estimates produced by the between and within estimators. The random effects estimators turn out to be equivalent to the estimation of z

$$(Y_{it} - \theta\bar{Y}_i) = (1-\theta)\,\alpha + (X_{it} - \theta\bar{X}_i)\beta + [(1-\theta)v_i + (\varepsilon_{it} - \theta\bar{\varepsilon}_i)] \qquad (9)$$

where θ is a function of the variances of ϑ and ε. If the variance of ϑ is always zero, then θ = 0 and equation (6) can be estimated by OLS directly. Alternatively, if the variance of ε is zero, θ=1 and the within estimator returns all the information.

Before using the fixed or random effect estimation, we perform tests to establish if the classical regression model with a single constant term is still appropriate. In case of the fixed effects model, the absence of fixed effects assumption can be readily tested using a F-test. To perform the test, the model is first estimated using OLS (under null H_0 that all the fixed effects are jointly zero), saving residual sum of squares, RRSS. Under the alternative hypothesis, the model is estimated under the fixed effects assumption, saving the residual sum of squares, URSS. We compute the following F-statistic

$$F = \frac{(RRSS\text{-}URSS) / (N + T - 2)}{URSS / (N-1)(T-1) - k}$$

to test the null hypothesis of no fixed effexts, where N is the total number of farms. If the null is rejected by the data, one can estimate the model under the asumption of fixed effects. In case of random effects, Lagrange muliplier test developed by Breuesch and Pagan (1980) and subsequently modified by Baltagi and Li (1990) is used. Under the asumption of no random effects, the test statistics is distributed as χ^2 (1). If the null hypothesis is true, then the variance of $(v_i+\varepsilon_{it})$ must be zero. If the test statistics is significant then we can reject the null hypothesis in favour of the random effects model.

In the case of OLS model being misspecified, the dabate is choosing between the fixed effects and random effects model. The fixed model suffers from lost degrees of freedom. On the other hand, there is no justification of assuming the individual effects, the υ_i's to be uncorrelated with the regressors, as is assumed in random effects model. To gain further insight, we perform Hausman's (1978) specification test.[8] If the model is correctly specified and if υ_i's are correctly uncorrelated with the regressors, then the two model should not differ systematically. Under the null hypothesis, the test statistic is distributed as χ^2(K). In case of the non-rejection of the hypothesis, the test suggests that the individual effects are uncorrelated with the regressors and therefore, the random effect models, is a better choice.

Chamberlain (1984) showed that the fixed effects model imposes testable restrictions on the parameters of the reduced form model and one should check the validity of these restrictions before adopting the fixed effects model. Mundlak (1978) argued that the random effects model assumes exogeneity of all the regressors with the random individual effects. So, it is an 'all' or 'nothing' choice of exogeneity of the regressors and the individual effects. Hausman and Taylor (1981) allowed for some of the regressors to be correlated with the individual effects, as opposed to all or nothing test. These over identification restrictions are testable using a Hausman-type test (Baltagi 2001). Following Baltagi (2001), and Angrist and Newey (1991), we perform a Chamberlain (1982) test. The rejection of the Chamberlain test can straightway guarantee the fixed effect model and in the case of the

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[8] Hausman test (1978): Suppose the individual effects are correlated with the regressors. In that case $\hat{\beta}$, the GLS estimates are baised and inconsistent for β, though the within estimates $\tilde{\beta}$ are still unbaised and consistent, because of the Within transformation wipes out the individual effects. Hausman (1978) suggests comparing these two estimates, both of which are consistent under the null H_0:$E(v_{it}|X_{it})=0$.

If $\hat{q}_1=\hat{\beta}-\hat{\beta}$, then the Hausman test (1978) is given by, $m_1=\hat{q}_1'[var(\hat{q}_1)]^{-1}\hat{q}_1$ and under the null, it is asymptotically distributed as χ^2_k, where K denotes the dimension of the slope vector β. Hausman and Taylor (1981) showed that H_o can in fact be tested using any of the following three paired differences:

$\hat{q}_1=\hat{\beta}_{GLS}-\bar{\beta}_{within}$; $\hat{q}_2=\hat{\beta}_{GLS}-\bar{\beta}_{between}$; or $\hat{q3}=\bar{\beta}_{within}-\bar{\beta}_{between}$ with the corresponding test statistics being $m_1=\hat{q}_1'[var(\hat{q}_1')]^{-1}\hat{q}_i$. These are asymptiotically distributed as χ^2_k for i = 1, 2,3 under H_0.

acceptance of the Chamberlain test, we take the alternative route suggested by Hausman and Taylor (1981) specification.

Chamberlain (1982) showed that the fixed effects specification imposes testable restrictions on the coefficients of the regressions of all leads and lags of dependent variables on all leads and lags of independent variables. Chamberlain specified the relationship between the unobserved individual effects and X_{it} as follows :

$$v_i = X'_{i1}\lambda_1 + \ldots\ldots + X'_{iT}\lambda_T + \varepsilon_i$$

where each λ_t is of dimenshion Kx1.

Let $y'_i = (y_{i1},\ldots, y_{iT})$ and $X'_i = (X_{i1},\ldots\ldots,X_{iT})$, and denote the reduced form of y'_i on X_i' by $y_i' = X_i'\pi + \eta_i$

The restrictions between the reduced form and structural parameters are given by $\pi = (I_T \otimes \beta) + \lambda\iota'_T$ with $\lambda_i' = (\lambda_{i1},\ldots, \lambda_{iT})$. Chamberlain (1982) suggested that estimation and testing be carried out using the minimum chi-square method where the minimand is a χ^2 goodness of fit statistic for the restrictions on the reduced form. Angrist and Newey (1991) showed that this minimand can be obtained as the sum of T terms, where each term is simply the degrees of freedom times the R^2 from a regression of the within residuals for a particular period on all leads and lags of the independent variables.

2.3 Examining changes in technical efficiencies

The panel estimation provides us with insights into changes in technical efficiency over time period, and changes in the levels of fragmentation. We wish to next examine whether this change is homogenous. That is over time and with the changes in the level of fragmentation, how do the farmers perform relative to each other. Technical efficiency is more a function of input management with a given technology rather than attempting to create endogenous technical change. Hence it is pertinent to ask whether farmers within each category (farm size) are homogenous in terms of their farm management practices. This will give insights into the need for addressing policies pertaining to land such as land ceiling and fragmentation.[9]

[9] The inefficiency of a farm as given in the stochastic frontier model (4)-(5) is partly explained by the input-usage associated with fragmentation. This association is non-linear in fragmentation. The value of farm size for which such an association would have maximum influence of inefficiency on the production function can be found from its partial derivative with respect to fragmentation.

2.4. Optimal Fragmentation

We remember that in the translog production function, we have used fragmentation as part of the production surface. We would like to know for each farm, how fragmentation affects the production function and hence the ability of an inefficient farm to improve efficiency or to reach the production surface.[10] This is important to know, for if f_z is larger, then it points to a need for a re-look at the policies pertaining to land reforms in order to quickly move towards optimum efficiency. We try to address this in the following way.

From our stochastic frontier (4)-(5), the contribution to inefficiency by fragmentation is given by

$$\sum_{j=1}^{7}\hat{\delta}_{ij}\,(x_{ijt} * f_z) + \sum_{j=1}^{7}\hat{\delta}_{ijt}\,(x_{ijt} * f_z^2)^2 + f_z + f_z^2 \qquad (10)$$

This implies that the inability of the farmer to produce the maximum potential output is partly explained by the factor inputs associated with fragmentation. This association is non-linear in fragmentation. We can solve for the fragmentation level, which would have no influence on the production function by taking the partial derivative of (10) with respect to fragmentation. This gives us the optimal level of fragmentation for that farm.

$$\frac{\partial}{\partial f_z}\left(\sum_{j=1}^{7}\hat{\delta}_{ij}\,(x_{ijt} * f_z) + \sum_{j=1}^{7}\hat{\delta}_{ijt}\,(x_{itj} * f_z^2) + f_z + f_z^2\right) = 0 \qquad (11)$$

This optimal level of fragmentation (f_z^*) is used to arrive at the new technical efficiency estimate (TE*) for each farmer. This will help us to see the change in technical efficiency arising out of a change in fragmentation levels.[11]

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[10] 'Best practice' farm is the farm that is supposed to be the most 'efficient' farm in the set of all farms considered for the analysis. Assuming that fragmentation is a factor influencing the production, the 'best practice' farm is defined as the farm, which consistently efficiently performs the best among all the farms, irrespective of the levels of fragmentation.

[11] From eq. 10 we are able to determine the variation in TE caused by change in fragmentation index and its interaction with other inputs. One of the objectives of land policy is to reduce or eliminate land fragmentation since it is perceived that fragmentation leads to lower levels of TE. This then implies that policy makers have in mind a certain optimal level of fragmentaion (if fragmentation is non-zero). This optimal level of fragmentation is expected to minimize the variation in TE caused by different levels of fragmentation. To determine this level of fragmentation, we take the partial derivative of eq.10 with respect to the fragmentation and solve for the optimal level of fragmentation index. This optimal level is obtained for each farmer. This optimal level of fragmentation index is used to compute the optimal level of technical efficiency or the new level of technical efficiency corresponding to the optimal levels of fragmentation.

CHAPTER 3

RESULTS

3.1. Crops and Input Usage

Factor input usage of the different crops is presented in Tables 2.1(i) to 2.1 (vi). The crops are cotton, *kuruvai* (rice), black gram and *samba* (rice). The two major crop sequences are Samba - Blackgram and Samba-cotton. Kuruvai is planted in May-June-early July and is a 90 day crop. *Samba* is planted from late August to November and is a 120 day crop. Blackgram is a secondary crop. It is a 60 day crop and is planted in January.

Table 2.1 : Descriptive statistics for input factor usage of the different crops

i) Cotton

Summary Statistics

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Mean	1629.90	528.75	190.13	156.02	7357.20	1460.30
Std. Dev.	1677.70	491.90	193.99	167.77	7933.10	2600.40
Min.	134.00	23.00	15.00	4.00	450.00	6.00
Max.	17144.00	4649.40	1888.80	1307.60	79039.00	21910.00

Correlation matrix

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Labor	1	0.91953	0.86362	0.7622	0.96616	0.65817
Harvest & Threshing labor		1	0.82967	0.73008	0.90071	0.60507
Land preparation labor			1	0.67169	0.85654	0.58762
Fertilizer & Manure				1	0.75856	0.4522
Bullocks & Machinery					1	0.66136
Irrigation						1

ii) Kuruvai

Summary Statistics

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Mean	603.62	497.78	340.94	9.18	2103.90	632.21
Std. Dev	675.41	687.76	349.86	7.82	2580.20	1525.10
Min.	8.00	8.00	5.00	1.00	6.00	1.00
Max.	5574.40	4812.80	2704.00	75.00	21299.00	21300.00

Correlation matrix

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Labor	1.0000	0.7850	0.8213	0.6288	0.7578	0.2467
Harvest & Threshing labor		1.0000	0.8111	0.5723	0.7137	0.1101
Land preparation labor			1.0000	0.6324	0.7421	0.1587
Fertilizer & Manure				1.0000	0.5002	0.1208
Bullocks & Machinery					1.0000	0.2286
Irrigation						1.0000

Note : All the summary statistics are in value (Rs.) terms and the correlation matrix expresses the relationship between input quantities.

iii) Blackgram

Summary Statistics

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Mean	997.10	592.62	—	—	5812.80	—
Std. Dev	1776.90	1160.40	—	—	10064.00	—
Min.	12.00	4.00	—	—	72.00	—
Max.	16659.00	11106.00	—	—	10242.00	—

Correlation matrix

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Labor	1.0000	0.9612	—	—	0.9204	—
Harvest & Threshing labor		1.0000	—	—	0.8960	—
Land preparation labor			—	—	0.9309	—
Fertilizer & Manure				—	0.9207	—
Bullocks & Machinery					1.0000	—
Irrigation						—

iv) Samba

Summary Statistics

	Labor	Harvest & Threshing labor	Land Preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Mean	713.61	306.37	118.95	79.57	4690.20	1636.80
Std. Dev.	521.70	312.12	74.77	73.54	4786.90	2993.20
Min.	40.00	5.00	1.00	3.00	200.00	6.00
Max.	3470.00	3650.00	1000.00	640.00	70000.00	25152.00

Correlation matrix

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Labor	1.0000	0.4895	0.3180	0.4773	0.5637	0.1100
Harvest & Threshing labor		1.0000	0.2274	0.3347	0.3503	0.0113
Land preparation labor			1.0000	0.1988	0.1708	0.0773
Fertilizer & Manure				1.0000	0.3105	0.0573
Bullocks & Machinery					1.0000	0.2235
Irrigation						1.0000

v) Samba-Blackgram

Summary Statistics

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Mean	1317.60	526.24	323.78	154.60	8066.60	1163.90
Std. Dev.	1277.90	607.28	1362.70	161.27	7892.70	2569.90
Min.	40.00	12.00	1.00	5.00	110.00	0.90
Max.	9762.40	5283.20	20400.00	1164.20	59378.00	20000.00

Correlation matrix

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Labor	1.0000	0.8464	0.0516	0.7368	0.9556	0.4593
Harvest & Threshing labor		1.0000	0.0910	0.6395	0.8514	0.3881
Land preparation labor			1.0000	0.4889	0.0512	0.0107
Fertilizer & Manure				1.0000	0.7185	0.3425
Bullocks & Machinery					1.0000	0.4538
Irrigation						1.0000

vi) Samba-Cotton

Summary Statistics

	Labor	Harvest & Threshing labor	Land preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Mean	1490.00	472.88	286.63	213.29	6749.10	1670.46
Std. Dev.	1451.40	433.30	329.10	226.97	6709.40	674.75
Min.	90.00	5.00	12.00	8.00	350.00	6.00
Max.	16079.00	3481.10	3814.40	2486.50	71445.00	8914.00

Correlation matrix

	Labor	Harvest & Threshing labor	Land Preparation labor	Fertilizer & Manure	Bullocks and Machinery	Irrigation
Labor	1.0000	0.9014	0.8169	0.8835	0.9330	0.6030
Harvest & Threshing labor		1.0000	0.7682	0.8292	0.9105	0.5285
Land preparation labor			1.0000	0.8474	0.8320	0.4698
Fertilizer & Manure				1.0000	0.8730	0.5562
Bullocks & Machinery					1.0000	0.5567
Irrigation						1.0000

a) From these results we notice that the labor use intensity for the two rice crops namely *kuruvai* and *samba* is not significantly different. However there is a significant difference in the levels of usage of fertilizer and bullocks and machinery. This reflects the fact that Samba is a long-term rice crop and is grown more extensively within the villages. Another reason is that *kuruvai* crop is derived from the high yielding short term varieties of rice that use less fertilizer and manure in general. The expenditure on land preparation is also significantly higher for *kuruvai* since the process involved is more complicated in terms of preparing more bunds and tilling of land while the land is still dry.

b) When we examine the two major crop-sequences samba-cotton and samba-blackgram we find that on an average the expenditure on labor is significantly higher in the sequence samba-cotton due to the prolonged harvest period of cotton. Another point we note is the use of irrigation for different crops. Blackgram requires no irrigation as it is grown as a secondary crop. The seeds are broadcast in the paddy fields that are growing samba roughly a fortnight before the harvest time for samba and is harvested roughly 45 days after the harvest of samba. The crop makes the use of irrigation for samba and the moisture that is retained by the soil. Also the samba crop is almost entirely irrigated by channels and as such irrigation through mechanized pump-sets (filter points) is usually not required.

3.2 Average Technical Efficiency

The average technical efficiency estimates of the crops/crop sequences by farm size are presented in Table 2.2.

Table 2.2 : Average technical efficiency estimates of the crops by farm size

Crop Type	0-2	2-4	4-10	Greater than 10
Cotton	0.633	0.601	0.532	0.425
Kuruvai	0.568	0.580	0.552	0.574
Blackgram	0.362	0.242	0.246	0.287
Samba	0.349	0.300	0.254	0.186
Samba-Blackgram	0.804	0.808	0.813	0.837
Samba-Cotton	0.940	0.952	0.913	0.931

We find that the average technical efficiency of farms growing crop sequences shows the highest levels of technical efficiency. This is irrespective of the farm size. However amongst those farmers growing a single crop we note that the smaller farmers namely 0 - 4 acres (0-2 acres for blackgram) are able to cultivate with relatively higher levels of technical efficiency. In fact the smallest size farms (0-2 acres) have the highest efficiency in all the four crops. The farmer usually opts between blackgram and cotton as the second crop. We note from this table that the technical efficiency of cultivating blackgram alone is quite low while the technical efficiency of cultivating cotton alone is high. Further the market for cotton is local in the sense that the traders come from nearby towns like Sirkhazi and Mayavarim. This contributes to a reduction of price uncertainty to the farmers. The blackgram prices on the other hand are extremely volatile. For example the price went down from 2500 / 50 kg bag in 1999-2000. The flip side of this uncertainy is the extremely low cost of cultivation for blackgram. In fact we observe that expenditure on land preparation labor, fertilizer and manure, and irrigation was non-existent. The crop is also less susceptible to pests, which is not the case for cotton. The farmers' perceive a risk arising out of markets for blackgram while for cotton, the risk arise out of pest attacks and water availability.

Technical efficients for crop sequences, surprisingly, do not vary much across farm size and are much higher than those for single crops.

3.3 Technical Efficiency and Fragmentation

The results of the impacts of fragmentation on the technical efficency of crops/crop sequences provide a feel for our definition of fragmentation index. We have worked out the index for some hypothetical cases

BOX: Fragmentation Index

To provide a feel for the fragmentation index, the table below shows fragmentation index for some hypothetical farms.

No. of plots	Fragmentation index			
	When all plots are of equal size	When largest plots covers X%of total farm area and other plots are of equal size		
		X = 90%	X=80%	X=50%
1	0			
2	0.50	0.188	0.32	0.5
3	0.67	0.1885	0.34	0.625
4	0.75		0.345	0.667
5	0.86		0.35	0.683
↓				
11	0.91	0.189	0.356	0.725

Table 2.3 : Average Technical efficiency estimates of the crops by the Fragmentation Index

	Fragmentation Index				
Crop Type	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1
Cotton	0.542	0.545	0.56	0.649	0.453
Kuruvai	0.817	0.847	0.852	0.859	0.817
Blackgram	0.306	0.44	0.449	0.343	0.365
Samba	0.698	0.636	0.293	0.116	0.047
Samba-Blackgram	0.620	0.538	0.349	0.212	0.108
Samba-Cotton	0.749	0.573	0.286	0.241	0.047

Fragmentation is usually perceived as an impediment to the optimal usage of different factors of cultivation, for different crops. We note that for the major crops of these villages mainly Samba and crop sequences of Samba-Blackgram and Samba-cotton, increased fragmentation leads to a significant decline in technical efficiency. Focussed group discussions with the farmers in these areas lead to the opinion that availibility of the paddy fields that are growing samba roughly a fortnight before the harvest time for samba and is harvested roughly 45 days after the harvest of samba. The crop makes the use of irrigation for samba and the moisture that is retained by the soil. Also the samba crop is almost entirely irrigated by channels and as such irrigation through mechanized pump-sets (filter points) is usually not required.

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Fragmentation is usually perceived as an impediment to the optimal usage of different factors of cultivation, for different crops. We note that for the major crops of these villages mainly Samba and crop sequences of Samba-Blackgram and Samba-cotton, increased fragmentation leads to a significant decline in technical efficiency. Focussed group discussions with the farmers in these areas lead to the opinion that availibility of water in this area through canals is an important factor affecting yields.

3.4 Distribution of Technical Efficiency

We note that there is a greater percentage of farmers with higher level of technical efficiency in the case of crop sequences namely Samba-cotton and Samba-Blackgram rather than when the farmers were growing individual crops. The distribution for cotton in fact seems to be bimodal. All of this seems to suggest that the managerial ability of farmers in these villages is not homogenous. Also nearly similar types of farmers seem to be growing the crop sequences samba-cotton and samba-blackgram. There is near homogeneity of farmer types within these groups.

3.5 Frontier Production Function: Does Fragmentation Affect Technical Efficiency?

Frontier Production Functions seek to explain the production frontier as a function of variables such as acreage, labour for different operations, fertilizer, irrigation, ownership of bullock and machinery, time (year), fragmentation index and technical inefficiency of the farm. At the same time technical inefficiency in turn is sought to be explained by a similar set of variables. Statistical tests are performed to see if the production frontier is neutral or not, neutral in the sense that the residuals seem to be independent of varous characterisitcs of the farm. From the estimates of the stochastic frontier production function, we observe that the frontiers for cotton and *kuruvai*, the functions are neutral. For blackgram, samba and crop sequences samba-blackgram and samba-cotton the frontiers are non-neutral.

a) *Cotton* – Cotton is grown immediately after the harvest of the long-term rice crop, samba (late December to March). The duration of this crop varies between 5-7 months. The yield is expected after the 3rd month. The peak yield is around the end of the 4th month and middle of the 5th month of the crop. Harvesting is completed by middle of July.

   We find that the frontier is neutral. The impact of fragmentatoin is significant but small. With fragmentaion, yield does go down.

b) *Kuruvai*- In the delta area of Kaveri river three crops of Rice during a growing season was the norm. This would include two successive short-term crops namely kuruvai and thaladi followed by a long-term crop namely Samba. In the period following the first water crisis precipitated by the Kaveri dispute between Karnataka and Tamil Nadu in the late 70's the acreage under Kuruvai has come down rather sharply. While the second short-term rice crop has rather vanished. Historically these two crops were the highest yielding for the farmers.

We notice that the frontier is neutral. The Chamberlain test rejects the fixed effect model in favor of the random effect model. We note here that the impact of time on technical change is positive and significant. It seems as though there is significant learning by doing that occurs endogenously with the passage of time. The coefficients of fragmentation, f_z, and f_z^2 are negative, large and significant. This implies that higher fragmentation lowers yield. The impact is substantial here. Fragmentation has serious negative effect on technical efficiency and output. The latter result entirely owes to the method of cultivation of *kuruvai* since water is no longer available in any of the canals for the cultivation of this crop. Irrigation has to be carried out through pump-sets (oil engines or energized). The command area of any given pump-set is roughly 2 acres. Also ground-water availability is also not uniform within these villages. The quality of ground water varies quite significantly as one moves to the eastern end of the village (salinity and sulphur content increases). Hence for optimal cultivation of this crop farmers with less fragmented holdings certainly will find it successful to achieve higher levels of techincal efficiency and output.

c) *Blackgram-* Blackgram is quite often grown as a secondary crop to samba. In fact there are very few farmers which have opted for cultivating blackgram alone in a significant part of their holdings. This crop cannot be grown in any other period apart from February to August. In the latter part of this period the moisture content of the soil is very low and irrigation is required for cultivation. This practice of irrigation is not adopted by the farmers due to variety of reasons such as the possibility of growing a more profitable crop such as cotton, lack of access to pump-sets (energized and otherwise) etc. The majority of the sub-sample of the 35 farmers that cultivate blackgram alone are either small or marginal farmers, i.e. less than 2 acres.

From the estimation we notice that the Stochastic Frontier is significantly non-neutral. We note that with the passage of time technical efficiency declines for these farmers. Increased fragmentation also reduces technical efficiency. The delta coefficients below the line define the technical inefficiency averaged over time for a particular farmer. They explain what determines technical inefficiency.

We notice that increased wage-gap between farm and non-farm wage rates leads to sharp reduction in technical efficiency as it would reduce the incentive of hired workers to work hard or only less efficient workers would be available for farm work. We also notice that fragmentation increases technical inefficiency.

d) *Samba*- Samba is the single most inportant crop in this part of the Kaveri delta. There are several reasons for this. These include creating the availibility of hay for cattle, output required for paying wages for agricultural workers, assured water supply through canals, assured procurement by the government of the output and the presence of the North-East monsoons. Samba was grown in 780 of the 825 cultivable acres in the year 1999-2000.

The non-neutral frontier is accepted over the neutral frontier. We note that with the passage of time there is significant decline in technical change. This is quite in contrast with kuruvai where we found that with the passage of time there were significant learning by doing effects.[1] An increase in fragmentation has substantial negative impact on technical efficiency. When we examine the impact of fragmentation as a factor contributing to inefficiency we notice that increased fragmentation has substantial negative impact on technical efficiency. When we examine the impact of fragmentation as a factor contributing to inefficiency we notice that increased fragmentation is in fact significant. Acreage (size of holdings of the farmers) is significant in explaining technical efficiency. In fact increased size holding will contribute to greater levels of technical efficiency. Casual impression based on discussions with the farmers in the area sugests that the land reforms leading to land distribution through the land ceiling acts have indeed contributed to certain anomalies in the cultivation of samba. We also note that both fragmentation and time contribute to the size of the non-neutrality effects.

There are many crop sequences that are grown in this part of the delta. Almost invariably the choice of the sequence depends on (in the decreasing order of importance) availibility of water, ability to supervise, soil quality and markets. The crop-sequences that are grown in the villages are kuruvai-samba-blackgram, samba-blackgram-groundnut, samba-blackgram and samba-

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[1] This perhaps is due to the fact that the group of farmers growing Samba is lot more heterogeneous than kuruvai (the number of farmers growing Kuruvai numbers only 25, the acreage under Kuruvai has varied between 50 and 55). Such heterogeneity might mask some of the farmers that are getting the benefit of learning by doing.

cotton. We choose to report the results for two of the most preferred sequences. We latter find that a very insignificant part of farmers whose size of the land holding exceeds 5 acres cultivates samba-blackgram. The preferred sequence for this category of farmers is samba-cotton.

e) *Samba-Blackgram-* this sequence is grown by a sub-sample of anywhere between 60-70 farmers in the reference period. Another 15-25 farmers cultivate the sequence in a part of their land holdings.

The non-neutral frontier is accepted over the neutral frontier. Fragmentation plays a significant role in explaining technical efficiency given the crop sequence level of fragmentation leads to a significant decline in technical efficiency.

Technical inefficiency is further explained by the delta coefficients in the table. Hired labor plays a crucial role in this particular sequence. Harvesting of both crops requires hired labor. This is irrespective of the farm size. We note that for this crop sequence increased use of hired labor leads to greater levels of technical inefficiency. This is as one can expect as hired labor would not be as productive as own labour. Though time does insignificantly explain in endogenous technical change, it however seems to have an effect on the ability of farmers to substitute between factors of production. This is indicative of a change in the structure of the factor markets over any given period of time. Similarly fragmentation also contributes to non-neutrality especially with respect to labor (both skilled and specialized). We also note from the results that the farm size[2] (denoted by acreage) plays a significant role in promoting technical efficiency. In fact it is seen that increased farm size contributes to greater levels of technical efficiency.

f) *Samba-Cotton-* We find that the sequence samba-cotton is increasingly being preferred by the farmers in this area. In fact for the reference period nearly 110 farmers either opted to grow cotton as a second crop in their entire holding or at least a part of the holding. It is increasingly becoming a staple second crop for smaller farmers. This is due to the fact that family provided labor does a large part of harvesting. Another reason is that the market for cotton is much more local with traders coming from

[2] Farm size refers to the total magnitude of land holding of the farm. This is not to be confused with the size of the plot.

nearby town like Sirkhazi and Mayavarim, which are within 15 kms from this village.

The non-neutral frontier is accepted. Fragmentation does seem to play a small but significant role in explaining endogenous technical efficiency.

Among the factors affecting technical inefficiency are fragmentation, wage gap and hired labour. The role played by the wage-gap may be noted. Cotton unlike Blackgram competes for labor with sources of employment such as brick-kilns and prawn farms. The wage rate in these other sources of employment and agriculture is nearly Rs. 30/ day. The existing wage-gap and any potential increase in this wage-gap will lead to a serious decline in technical efficiency.

3.6 Optimal Fragmentation

If farmers can choose their fragmentation level what should they choose? The optimal level may depend on the circumstance and resources of each farmer. We explore this question using the estimated frontier production functions. We maximize yield with respect to fragmentation index, f_z, to obtain optimal fragmentation which we donote by f_z^*. The corresponding TE we call optimal TE and denote by TE^*. The results are presented in the form of scatter diagrams.

It is interesting to see that f_z^* does not exceed 0.6 which is more consolidation than represented by 3 equal sized plots which would have a fragmentation index of 0.67.

For only Samba growing farmers, optimal fragmentation index is even smaller. Excepting two plots, f_z^* is less than 0.3 which means more consolidation than one reflected by two equal plots.

For those who grow crop sequences of samba-cotton and samba-blackgram, the optimal fragmentation index is less than around 0.5 and 0.6 respectively. With crop-diversification optimal fragmentation level is higher.

3.7 Gain from Consolidation

To see the gain from consolidation we plot percentage gain in TE against f_z. It is seen that both absolute gains and percentage gains are sizeable and larger for highly fragmented holdings. For samba-blackgram the absolute gains are rather small but for samba-cotton and samba they are substantial.

3.8 Technical Efficiency and Fragmentation: Conclusions

(a) We have seen that in the village fragmentation affects technical efficiency adversely for the most important crop samba and samba-blackgram and samba-cotton. Also the impact is large.

(b) For farmers growing single crop of cotton, kuruvai or blackgram the impact is not pronounced.

(c) We also see that optimal consolidation would lead to farmers having equivalent of less than 3 equal plots and mostly much more consolidation than that.

(d) The gains from consolidation are also large in terms of technical efficiency.

(e) The puzzle remains. If fragmentation leads to inefficieny, why do not market forces induce farmers on their own to consolidate at least their operational holdings?

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