FORMATION AND EFFICIENT ESTIMATION OF STOCHASTIC FRONTIER PRODUCTION FUNCTIONS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Formation and Efficient Estimation of Stochastic Frontier Production Functions**" is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled "**Formation and Efficient Estimation of Stochastic Frontier Production Functions**" is a record of research work done independently by **Sri. Dhanesh, N. J,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Dhanesh, N. J.

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ABBREVIATIONS

AE	Allocative Efficiency
ANOVA	Analysis of Variance
COLS	Corrected Ordinary Least Squares
DEA	Data Envelopment Analysis
EE	Economic Efficiency
EM	Expectation Maximization
Kg.	Kilogram
MFC	Marginal Factor Cost
MVP	Marginal Value Product
PC	Present Cost
PV	Present Value
Rs.	Rupees
RTS	Return To Scale
SFA	Stochastic Frontier Analysis
SFPF	Stochastic Frontier Production Function
Std.	Standard
TE	Technical Efficiency

INTRODUCTION

1. INTRODUCTION

Due to lack of reliable data very little is known about actual technical change and productivity growth in the farming communities and productivity is an important indicator that represents the growth of each economic agent. Economists and policy makers have studied productivity for a long time. This is because in the long run, only productivity growth is considered as an engine for economic growth. Technical efficiency is just one component of overall economic efficiency. However, in order to be economically efficient, a firm must first be technically efficient. Profit maximization requires a firm to produce the maximum output given the level of inputs employed (i.e. be technically efficient), use the right mix of inputs in the light of the relative price of each input (*i.e.*, be input allocative efficient) and produce the right mix of outputs given the set of prices (i.e. be output allocative efficient) (Kumbhaker and Lovell, 2000). Technological change and efficiency improvement are important sources of productivity growth in any economy.

The concept of technical efficiency is based on input and output relationships. Technical inefficiency arises when actual or observed output from a given input mix is less than the maximum possible. Allocative inefficiency arises, when the input mix is not consistent with cost minimization criteria (Coelli, 1996; Wang and Schmidt, 2002). In the case of saw mills, allocative inefficiency occurs when millers do not equalize marginal returns with true factor prices. Relative productive efficiency of firms within an industry is continually shocked by economic events as well as the process of adopting technical innovations. The diffusion of new and more efficient methods is, often, a slow, drawn-out affair. The analysis of technical efficiency involves the assessment of the degree to which production technologies are being utilized.

As plantation crops sector is concerned, the measurement of technical efficiency is very much necessary towards improvement of production. Availability of reliable data is a major problem towards assessing the exact technical efficiency. A plantation crop has to encompass various stages of growth before being actually profitable to the planter. The cost involved at various stages of growth is also very important. Vary rarely records are being kept of the exact costs involved at various stages of crop growth. Estimation of exact costs involved is a major problem. A rationalized approach is very much necessary for estimation of exact costs. Usually stochastic frontier production functions are fitted to crops, which are of short duration. Very rarely works have been conducted in plantation crops. With this concept in mind, a study was done to assess the present economics of pepper cultivation with the under mentioned objectives.

(i) To formulate new stochastic frontier production functions

(ii) To compare the different methods of estimation of the frontier functions

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Stochastic frontier approach has found wide acceptance within the agricultural economics literature because of its consistency with theory, versatility and relative ease of estimation. The measurement of efficiency (technical, allocative and economic) has remained an area of important research both in the developing and developed countries.

This is especially important in developing countries, where resources are meager and opportunities for developing and adopting better technologies are dwindling. Efficiency measures are important because it is a factor for productivity growth. Such studies benefit these economies by determining the extent to which it is possible to raise productivity by improving the neglected source of growth i.e. efficiency, with the existing resource base and available technology.

Sahota (1968) evaluate the efficiency of Indian farmers in allocating resources available to them among different production alternatives. For this purpose, production functions were estimated and marginal productivities were derived for various agricultural inputs for different crops and farm sizes across different states in India. The final evaluation of resource allocation consists mainly of comparisons between the computed marginal value products and the corresponding input prices over different dimensions. Such an analysis of the present agriculture of India is particularly desirable for formulating future plans for the agricultural development of the food-hungry India of today.

Timmer (1971) uses linear programming techniques to "estimate" a frontier Cobb-Douglas production function for U.S. agriculture from 1960 to 1967, using the "average farm" in each state in each year as an observation. Both deterministic and probabilistic frontiers are generated and the results compared with ordinary least squares and analysis of covariance estimates of the production function. Technical inefficiency is defined relative to the probabilistic frontier function and the extent of any inefficiency calculated for each state. Little technical inefficiency exists across states when the production function includes intermediate inputs as well as land, labour and capital.

Meeusen and Broeck (1977) taking into account the purely statistical definition of efficiency arrived at an average sectoral efficiency for the industries at issue, which lied, between 0.70 and 0.94. There was no significant statistical relationship between this efficiency measure and that of Richmond's. The evidence from the limited number of industries, which were examined, was not conclusive in finding a relationship between the efficiency phenomenon and the other structural characteristics of the production process. The aprioristic choice of the exponential distribution for the efficiency variable and, for that matter, of the Cobb-Douglas specification itself was, of course, debatable.

Huang (1984) considers the estimation of the stochastic frontier production function and its technical inefficiency for each observation by estimating the sufficient statistics of the latent variable of the stochastic frontier production. Expectation maximization (EM) algorithm of estimating the stochastic frontier production function is presented in his study. The algorithm provides an alternative way of the estimating technical inefficiency for each observation in the sample. The iterative solution of the EM algorithm leads to the maximum likelihood estimate. However, the main advantage of the algorithm is that it can be obtained through the ordinary least squares computation program, which is simpler to implement than the Davidson-Fletcher-Powell optimization algorithm. The posterior density of the ratio of the variance is used to make an inference about the stochastic frontier specification for Indian agriculture. The paper also demonstrates the use of the conditional posterior density function to investigate the sensitivity of the estimates to the specification of the stochastic frontier production function.

Belbase and Grabowski (1985) attempted to measure the technical efficiency (TE) of a sample of 537 Nepalese farmers. The method used was corrected ordinary least squares. From the estimation incorporating four crops (rice, maize, wheat, and millet), technical efficiency ratios, reflecting the ratio of actual to potential output, were constructed. The results seemed to show that with all observations included, the average technical efficiency ratio was 76 percent. With the greatest data outlier eliminated, the average technical efficiency ratio was 80 percent. In addition, the corrected ordinary least squares (COLS) method was used to derive technical efficiency ratios for rice and maize separately.

Battese and Coelli (1986) proposed an application of stochastic frontier production function to the dairy industries. It indicated that the traditional Cobb-Douglas production function was not a suitable model. The frontier model with asymmetric errors having half-normal distribution appeared to be adequate for both states. This contrasted with the findings of Stevenson (1980) in an application involving only cross-sectional data for the U.S. Primary Metals Industry.

Battese and Coelli (1988) obtained the best predictor for the firm-effect random variable and the appropriate technical efficiency of an individual firm, given the values of the disturbances in the model. The results obtained are a generalization of those presented by Jondrow *et. al.* (1982) for a cross-sectional model in which the firm effects have half-normal distribution. The model is applied in the analysis of three years of data for dairy farms in Australia. The application of stochastic frontier production functions to the dairy industries in New South Wales and Victoria indicates that the traditional (average) Cobb-Douglas production function is not a suitable model. Given that the generalized frontier model applies, then the half-normal distribution is not an adequate representation for the individual firm effects, which determine technical efficiencies of farms. This concurs with the findings of Stevenson (1980) in an application involving only cross-sectional data for the U.S. Primary Metals Industry. The more general model for describing firm effects in frontier production functions accounts for the situations in which there is high probability of firms not being in the neighborhood of full technical efficiency. This is not the case for the half-normal and exponential distributions. However, it is obvious that further research is required on the modelling of technical efficiencies of firms over time for different industries.

Kumbhakar *et. al.* (1989) investigated the technical, allocative and scale inefficiency of owner operators of dairy farms in Utah. A stochastic production frontier was applied to analyze these inefficiencies. The results indicated that there is positive association between years of education and productivity of labour and capital. Productivity was also found to be negatively related to off farm income. Regarding the effects of farm size on efficiency it was found that, large farms were the most efficient of all sizes considered. Separate estimates of technical, allocative and scale inefficiencies indicated that large and medium sized farms were technically more efficient than small farms. Large farms, on average, were found to be performing much better than medium sized and small farms so far as allocative and scale inefficiencies were concerned.

Dawson *et. al.* (1991) observed the single measures of farm-specific technical efficiency over time calculated for rice farms in Central Luzon, Philippines, from the residuals of a stochastic frontier production function. Panel data from the International Rice Research Institute's periodic "Loop Survey" was used. Results showed a narrow range of efficiency between 84 percent and 95 per cent across the twenty-two farms, so that there was limited scope for increasing output by resource reallocation. A comparison was made with measures of technical efficiency using traditional covariance analysis.

Kumbhakar *et. al.* (1991) investigated farm-level efficiency of U.S. dairy farmers by estimating their technical and allocative efficiency (AE). Technical inefficiency was assumed to be composed of a deterministic component that was a function of some farm-specific characteristics and a random component. Given the inputs, variations in efficiency of farms are then explained by both deterministic and random components of technical inefficiency. The empirical results indicated that levels of education of the farmer were important factors determining technical inefficiency and large farms were more efficient (technically) than small and medium-sized farms. Both technical and allocative inefficiency were found to decrease with increase in the level of education of the farmer.

Battese and Coelli (1992) discussed the importance of frontier production functions for the prediction of technical efficiencies of individual firms in an industry. A stochastic frontier production function model for panel data was presented, for which the firm effects were an exponential function of time. The best predictor for the technical efficiency of an individual firm at a particular time-period was presented for this time-varying model. An empirical example presented using agricultural data for paddy farmers in a village in India, revealed that the technical efficiencies of the farmers were not time invariant when year of observation was excluded from the stochastic frontier. However, the inclusion of year of observation in the frontier model led to the finding that the corresponding technical efficiencies were time invariant. In addition, the stochastic frontier was not significantly different from the traditional average response function. This implied that, given the state of technology among paddy farmers in the Indian village involved, technical inefficiency was not an issue of significance provided technical change was accounted for in the empirical analysis.

structure, suggested by Just and Pope (1978), and the stochastic frontier production function model, proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977).

Battese and Tessema (1993) gives the specifications of a literalized version of the Cobb-Douglas production frontier with coefficients which are a linear function of time, the hypothesis of time-invariant technical inefficiency is rejected for one of the three villages involved. The hypothesis of time invariant coefficients of the explanatory variables is rejected for two of the three villages. Further, the hypothesis that hired and family labour are equally productive is accepted in only one of the three villages.

Battese and Coelli (1993) observed in the empirical application of the inefficiency stochastic frontier production function some interesting differences from those obtained in the application of the time-varying inefficiency model presented by Battese and Coelli (1992). With the latter model, it was concluded that there was no evidence of technical inefficiencies of production with essentially the same sample of paddy farmers. However, the Battese and Coelli (1992) model assumed that the technical inefficiency effects were the product of an exponential function of time and non-negative firm-specific random variables. The present model specified that the inefficiency effects were a linear function of some firm-specific variables and time, together with an additive stochastic error, which was assumed to be independent over time and among firms. The two models involved were clearly separate and so it was difficult to conclude which was the "best" model for the data involved. However, the logarithm of the likelihood function for the data was greater under the assumptions of the above inefficiency stochastic frontier model than for the Battese and Coelli (1992) model. Further theoretical and applied work was obviously required to obtain better and more general models for stochastic frontiers and the inefficiency effects involved.

Environment and Production Technology Division and International Food Policy Research Institute (Fan, 1999) developed a frontier shadow cost function approach to estimate empirically the effects of technological change, technical and allocative efficiency improvement in Chinese agriculture during the reform period (1980-93). The results revealed that the first phase rural reforms (1979-84) which focused on the decentralization of the production system had a significant impact on technical efficiency but not an allocative efficiency. During the second phase reforms which were supposed to focus on the liberalization of rural markets, technical efficiency improved very little and allocative efficiency increased only slightly. In contrast, the rate of technological change continued to increase, although at a declining rate during the second phase reform.

Battese (1992) seeks to update the econometric modelling of frontier production functions associated with the estimation of technical efficiency of individual firms. A survey of empirical applications in agricultural economics is an important part of the paper. Frontier production functions have been applied to farm-level data in many developed and developing countries. These empirical analyses have yielded many useful results and suggested areas in which further research is required. It is expected that further advances will be made in the next few years in the development of less restrictive models (e.g., time varying technical efficiency) and more complete econometric systems. Such modelling will offer significant stimulus to better empirical analysis of efficiency of production.

Wan and Battese (1992) considered a new stochastic frontier production function which permitted the marginal production risks of inputs to be negative or positive and the technical efficiency of firms to be a function of the levels of the factor inputs. Previous frontier production function models, which have specified either zero or positive marginal risks, did not permit sufficient flexibility for many empirical applications. The proposed frontier model incorporates the production risk structure, suggested by Just and Pope (1978), and the stochastic frontier production function model, proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977).

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Bravo-Ureta and Evenson (1994) concluded that paraguan cotton had 40.1 percent average economic efficiency while cassava producers were 52.3 percent efficient and as such there was room for improvement in productivity for these basic crops. However they did not find a relationship between economic efficiency (EE) and socioeconomic characteristics. This observation was explained by the possibility of existence of a stage of development threshold below which this type of relationship was not observed.

Pope and Chavas (1994) investigated the consistency of expected utility maximization models with cost minimization when production is uncertain. It was not generally possible, assuming risk aversion, to use only expected output as the constraint in a cost minimization problem. In some leading cases, cost functions consistent with expected utility maximization are particularly useful because they were devoid of risk preferences. They showed that consistency of cost minimization with expected utility maximization imposes some structure on production technology. This structure is satisfied by many commonly used agricultural production functions. Thus, there is a readily implementable approach to defining appropriate cost functions under production uncertainty

Johnson *et. al.* (1994) evaluated that Ukraine's public sector farms responded to a system of incentives and policies characterized by regional development objectives and lack of trade between farms. The results from 1986 to 1992 indicated little evidence of economies of scale, declining technical efficiency in crop production, and considerable variability in technical efficiency among farms. With no evidence of economies of scale, there was little support in the data for policies aimed at restructuring the farm sector through breaking up of the large farms.

Battese and Coilli (1995) studied the technical inefficiency effects in a stochastic frontier production function proposed for panel data. It was defined for panel data on firms, in which the non-negative technical inefficiency effects were assumed to be a function of firm-specific variables and time. The inefficiency effects were assumed to be independently distributed as truncations of normal distributions with constant variance, but with means which were a linear function of observable variables. The panel data model was an extension of recently proposed models for inefficiency effects in stochastic frontiers for cross-sectional data. An empirical application of the model was obtained using upto ten years of data on paddy farmers from an Indian village. The null hypotheses, that the inefficiency effects were not stochastic or do not depend on the farmer specific variables and time of observation, was rejected for these data.

Parikh *et. al.* (1995) evaluated the behavioral and stochastic cost frontier functions applied to estimate cost inefficiency by farms. The behavioral approach satisfied most of the assumptions of dual cost function and the likelihood ratio test rejected the market efficiency hypothesis implying less than optimum use of manures, labour, and fertilizers. A measure of inefficiency based on a stochastic cost frontier approach confirmed the results of the behavioral approach. They used survey data on input costs and aggregate output by farms to measure farm level inefficiency using a "residual" approach. They imposed less structure in the cost frontier approach by using a flexible functional form. Cost inefficiency was estimated using a translog cost frontier. The results showed that farmers were inefficient by Farrell's measure of cost inefficiency. The average level of inefficiency was 11.5 per cent, and the level of inefficiency ranged from 41.5 to 3.0 per cent by individual farms. The estimated values of inefficiency were then regressed on variables such as education, extension, availability of credit, and land tenure. This approach assumed that these explanatory variables were independent of input decisions. This limitation was removed by introducing shadow prices and extra parameters in the measurement of allocative inefficiency in the first stage estimation.

Battese *et al.* (1996) used a single stage stochastic frontier model to estimate technical efficiencies in the production of wheat farmers in four districts of Pakistan ranging between 57 and 79 percent. The older farmers had smaller technical inefficiencies.

Wang *et. al.* (1996) examined Chinese farm household's production efficiency. Given a mixed government-controlled and free-market economy, the observed prices used in the analysis were an average of government-controlled prices, semi-controlled prices, and free-market prices. Furthermore, prices that farmers actually paid (received) were different from observed prices because of some market restrictions other than direct government control. The prices that farmers actually paid (received) were not directly observed. Since profit-maximizing producers' production decisions are based on prices they actually paid (received), farm households' profit efficiency analysis required that the relationship between observed prices and unobserved prices be modeled.

Najma and Atul (1996) examines a sample of farmers from Bangladesh, in order to study inter and intra crop patterns of technical efficiency in rice cultivation by estimating stochastic production frontiers, as well as to assess the role of household endowments (e.g. education, land ownership) and other characteristics in explaining farmer differences in efficiency. What makes the analysis especially interesting was that, of the three rice crops harvested in our sample economy, two were more traditional, while the third was of the new technology, high yielding variety (HYV), which had spearheaded the so-called "Green Revolution" in rice. Of particular interest was the question of how successful farmers had been in adapting to the technically more demanding HYV crop vis-a-vis traditional crops.

Ali *et. al.* (1996) estimated the cost inefficiency by farms using behavioral and stochastic cost frontier functions. The derived measure of inefficiency based on half-normal and/or exponential distribution of one-sided error term was related to socioeconomic variables, and of these, the size of holding, fragmentation of land, subsistence needs, and higher age of farmers contributes positively to inefficiency. The behavioral approach satisfied most of the assumptions of the dual cost function, and the likelihood ratio test rejects the market-efficiency hypothesis. The average inefficiency was 11.5 percent, with a maximum being 41.5 percent and minimum 3.0 percent. This indicated that a substantial amount of extra cost was incurred due to inefficiency. This approach asserts that there was less than optimum use of manures, labor, and fertilizers. The non-optimum use was explained by holding size, education, credit, and subsistence needs. Small farms seemed to be more efficient than large farms in the region.

The study of Bravo-Ureta and Pinheiro (1997) revealed average level of technical, allocative, and economic efficiency equal to 70 per cent, 44 per cent, and 31 per cent, respectively. These results suggested that substantial gains in output and/or decreases in cost could be attained given existing technology. The results also pointed to the importance of examining not only TE, but also AE and EE when measuring productivity.

Bedassa and Krishnamoorthy (1997) used a two-step approach to estimate technical efficiency in paddy farms of Tamil Nadu in India. They concluded that the mean technical efficiency was 83.3 percent, showing potential for increasing paddy production by 17 percent using present technology. Small and medium-scale-farmers were more efficient than the large-scale farms. In addition, the study concluded that animal power was over utilized and therefore suggested reduction. However, the paddy farmers could still benefit by increasing the fertilizer use and expansion of land.

In measuring technical efficiency of maize producers in Eastern Ethiopia for farmers within and outside the Sawakawa-Global 2000 project, Seyoum *et al.* (1998) used a translog stochastic production frontier and a Cobb-Douglas production function. Some of the key conclusions from this study were that younger farmers were more technically efficient than the older farmers. In addition, farmers with more years of school tended to be more technically efficient. On the other hand, those that obtained information from extension advisers tended to reduce the technical inefficiency. The mean technical efficiency of farmers within the Sawakawa-Global 2000 project was estimated to be 0.94 while that the estimate of the farmers outside the project was 0.80.

A study by Wilson *et al.* (1998) on technical efficiency in UK potato production used a stochastic frontier production function to explain technical efficiency through managerial and farm characteristics. Mean technical efficiency across regions ranged from 33 to 97 percent. There was high correlation between irrigation of the potato crop and technical efficiency. The number of years of experience in potato production and small-scale farming were negatively correlated with technical efficiency.

Sedik *et. al.* (1999) considered how Russian corporate farm efficiency had changed in the period from 1991 to 1995 and why, using oblast level data. Both time series and cross-section efficiency results pointed to the overwhelming importance of *initial conditions in predicting farm efficiency performance. Efficiency scores could* be explained by several economic and institutional factors, including farm size, softness of the budget constraint, and deterioration in farm terms of trade and oblast-level specialization of production. The overall results of the study were more consistent with a corporate farm sector that followed a policy of oblast self-sufficiency than with one engaged in actual restructuring.

Kyi and Oppen (1999) dealt with issues of improving efficiency and productivity on irrigated rice in Myanmar. It used the stochastic frontier analysis approach to the estimation of production functions from cross-sectional data during the 1997 crop season. The empirical results indicated that in the sample irrigated area seed rate use in rice production would have an important role in increasing total output. In addition, in order to increase efficiency of the rice farms it is required to improve the human resource capability and extension knowledge for the improvement of rice productivity. The significant technical inefficiency effects exist for large farmers who used fertilizer and for small and large farmers who did not use fertilizer. The empirical results showed that most farmers have high scores of technical efficiency. The estimated mean technical efficiencies for small, medium and large farmers who used fertilizers were 97, 90 and 92 percent respectively, i.e., small farmers were more efficient than the large farmers. For farmers not using fertilizer, technical efficiency scores were 88, 92 and 93 percent respectively.

Dhawan and Jochumzen (1999) investigated the impact of measurement errors of the inputs on estimates of production function parameters and firm-specific technical efficiency estimates in a cross sectional SFPF setting. They developed a procedure for estimating parameters of a cross-sectional stochastic frontier production function (SFPF) when input variables suffered from measurement errors. Specifically, they used Fuller's (1987) reliability ratio concept to develop an estimator for the model in Aigner, Lovell and Schmidt (1977).

A study by Liu and Zhuang (2000) on technical efficiency in post-collective Chinese Agriculture concluded that 76 and 48 percent of technical inefficiency in Sichuan and Jiangsu, respectively, could be explained by inefficiency variables. They used a joint estimation of the stochastic frontier model and estimated a stochastic frontier production function model, which explained a considerable proportion of inter farm efficiency differences. An important determinant of farm efficiency was liquid resource available to household farms.

Mihai *et. al.* (2000) investigates the time-path of efficiency and productivity change in the case of the Romanian cement industry 1966-1989. The analysis was based on different specifications of stochastic frontier models. The efficiency scores and the time paths of efficiency and technical change were found to vary substantially among models. The most important feature of the Romanian cement industry before the revolution in 1989 was a slow rate of productivity progress, and a corresponding catch up in the level of productive efficiency.

Abdulai and Huffman (2000) studied economic efficiency of rice farmers in Northern Ghana using a normalized stochastic profit function frontier. They concluded that the average measure of inefficiency was 27 percent, which suggested that about 27 percent of potential maximum profits were lost due to inefficiency. The discrepancy between observed profit and frontier profit was due to both technical and allocative inefficiency. Higher levels of education reduced profit inefficiency while engagement in off-farm income earning activities and lack of access to credit, experienced higher profit inefficiency. The study also found significant differences in inefficiencies across regions.

Dey *et. al.* (2000) examined the technical efficiency of tilapia growout of operations in ponds in the Philippines. A stochastic production frontier with technical inefficiency effects model was specified and estimated. The estimated mean technical efficiency of the 78 farmers in the sample was 83 percent. Total farm area, education and age of the farmers were some of the factors affecting technical efficiency. Those with a larger farm area, higher age and a higher educational level attain higher technical efficiency. As growers in the Philippines have attained a high level of technical efficiency under existing technology, the introduction of new technology was a key to raising the productivity of tilapia farming. The genetically improved farmed tilapia (GIFT) strain that had recently become available provided a promising new technology to raise the productivity and output of tilapia farming.

Greene, W. H. (2000) evaluated normal-gamma stochastic frontier model, which was proposed by Greene (1990), and Beckers and Hammond (1987) as an extension of the normal exponential proposed in the original derivations of the stochastic frontier by Aigner, Knox Lovell, and Schmidt (1977). The normal-gamma model had the virtue of providing a richer and more flexible parameterization of the inefficiency distribution in the stochastic frontier model than either of the canonical forms, normal-half normal and normal-exponential. However, several attempts to operationalize the normal-gamma model have met with very limited success, as the log likelihood is possessed of a significant degree of complexity. This note would propose an alternative approach to estimation of this model based on the method of simulated maximum likelihood estimation as opposed to the received attempts which have approached the problem by direct maximization.

Kumbhakar (2001) dealt with derivation and implications of profit functions when profit was not maximum due to the presence of either technical inefficiency or allocative inefficiency, or both. Estimation techniques were developed for both cross-sectional and panel data models. Working of the model was illustrated using a panel of 60 salmon farms.

Abdulai and Eberlin (2001) used a translog stochastic frontier model to examine technical efficiency in maize and beans in Nicaragua. The average efficiency levels were 69.8 and 74.2 percent for maize and beans, respectively. In addition, the level of schooling represented human capital, access to formal credit and farming experience (represented by age) contributed positively to production efficiency, while farmers' participation in off-farm employment tended to reduce production efficiency. Large families appeared to be more efficient than small families. Although a larger family size did put extra pressure on farm income for food and clothing, it ensured availability of enough family labour for farming operations to be performed on time. Positive correlation between inefficiency and participation in non-farm employment suggested that farmers reallocate time away from farm-related activities, such as adoption of new technologies and gathering of technical information that is essential for enhancing production efficiency. The result indicated that efficiency increased with age until a maximum efficiency was reached when the household head was 38 years old. The age variable probably picked up the effect of physical strength as well as farming experience for the household head.

In a study by Wilson *et al.* (2001) a translog stochastic frontier and joint estimate technical efficiency approach was used to assess efficiency. The estimated technical efficiency among wheat producers in Eastern England ranged between 62 and 98 per cent. It was found that the farmers who sought information had more years of managerial experiences, had large farms and were associated with higher levels of technical efficiency.

A study by Mochebelele and Winter-Nelson (2002) on smallholder farmers in Lesotho used a stochastic production frontier to compare technical inefficiencies of farmers who sent migrant labour to the South African mines and those who did not. They concluded that farmers who sent migrant labour to South African were closer to their production frontier than those who did not.

Belen *et al.* (2003) tried to estimate technical efficiency in the horticultural production in Navarra, Spain. They estimated that tomato producing farms were 80 percent efficient while those that raised asparagus were 90 percent efficient. Therefore, they concluded that there existed a potential for improving farm incomes by improving inefficiency.

Gautam and Jeffrey (2003) used a stochastic cost function to measure efficiency among smallholder tobacco cultivators in Malawi. Their study revealed that larger tobacco farms were less cost inefficient. The paper uncovered evidence that access to credit retards the gain in cost efficiency from an increase in tobacco acreage. This suggested that the method of credit disbursement was faulty.

Binam *et. al.* (2003) evaluated the measures of technical efficiency for a sample of 81 peasant farmers in the low-income region of Coˆ te d'Ivoire. Data envelopment analysis (DEA) techniques were used to compute farm level technical efficiency (TE) measures. The analysis revealed average levels of technical efficiency equal to 36 per cent and 47 per cent respectively for the Charnes *et. al.* (1978) and Banker *et. al.* (1984) models. These results suggested that substantial gains in output and/or decreases in cost could be attained given the existing technology. In a second step analysis, two-limit Tobit regression techniques were used to examine the relationship between TE and various farm/ farmer characteristics. From a policy point of view, an important conclusion stemming from the analysis of the sample was that family size, membership to farmer's club or association and the origin of the farmer were the variables found to be most promising for action. The analysis suggested that policymakers should foster the development of the formal farmers' club or association by building the capacity of the farmers.

Wadud (2003) assessed estimates of technical, allocative and economic efficiency of farms using farm-level survey data for rice farmers in Bangladesh. Applying the stochastic efficiency decomposition technique and DEA, inefficiency effects were modeled as a function of farm specific human capital variables, irrigation infrastructure and environmental factors. The results from both the approaches showed that there was substantial technical, allocative and economic inefficiency in production and that analysis of technical, allocative and economic inefficiency in terms of land fragmentation, irrigation infrastructure and environmental factor were robust. Policies leading to reduction of land fragmentation and improvement of irrigation infrastructure and environmental factors could promote technical, allocative and economic efficiency, reduce yield variability and enhance farm income and household welfare.

Murillo-Zamorano (2004) provided a critical and detailed review of both core frontier methods. In their opinion, no approach was strictly preferable to any other. Moreover, a careful consideration of their main advantages and disadvantages, of the data set utilized, and of the intrinsic characteristics of the framework under analysis helped in the correct implementation of these techniques. Recent developments in frontier techniques and economic efficiency measurement such as Bayesian techniques, bootstrapping, duality theory and the analysis of sampling asymptotic properties were also considered.

Ahmed *et. al.* (2005) examined the influence of the conventional agricultural inputs on sorghum production levels in the Gezira scheme, to investigate the main factors behind tenants technical inefficiency and to evaluate their implications on the food security at household level. Stochastic frontier production function was estimated using a sample of 100 tenants in the Gezira Scheme. The results showed that credit, capital, hired labour, fertilizer and irrigation had significant positive effects in sorghum production levels, while sorghum area showed a negative and significant effect. An average of technical efficiency of 67 percent for sorghum production was found, implying that room to increase sorghum yield through the better use of the tenants available resources exist. Size of holding, education level, tenants experience, household size, contact with extension agents and farm location were significant in explaining tenants' technical inefficiency.

Hassan and Ahmad (2005) evaluated the technical efficiency of the wheat farmers in the mixed farming system of the Punjab by using stochastic frontier production function, incorporating technical inefficiency effect model. The Cobb Douglas production function was found to be an adequate representation of the data, given the specification of the corresponding translog frontier model. The technical inefficiency effects were found present and contained a significant random element. The technical inefficiency effects were found to be a linear function of different firm specific factors. The individual impacts of some of the variables in the inefficiency effect model were non-significant, but the combined influence of all the ten variables was significant in reducing the inefficiency of the wheat farmers in the mixed farming system of Punjab and Pakistan. The results also indicated that the farmers were operating at constant returns to scale.

Msuya and Ashimogo (2005) estimated the levels of technical efficiency of 233 smallholder maize farmers in Tanzania and provided an empirical analysis of the determinants of inefficiency with the aim of finding way to increase smallholders' maize production and productivity. Results showed that smallholder productivity was very low and highly variable, ranging from 0.01 t/ha to 6.77 t/ha, averaging 1.19 t/ha. Technical efficiencies of smallholder maize farmers ranged from 0.01 to 0.91 with a mean of 0.61. Low levels of education, lack of extension services, limited capital, land fragmentation, and unavailability and high input prices were found to have a negative effect on technical efficiency. Smallholder farmers using hand-hoe and farmers with cash incomes outside their farm holdings (petty business) were found to be more efficient. However, farmers who used agrochemicals were found to be less efficient. Policy implications drawn from the results included a review of agricultural policy with regard to renewed public support to revamp the agricultural extension system, and interventions towards improving market infrastructure in order to reduce the transaction element in the input and output marketing.

Bokusheva and Hockmann (2006) investigated production risk and technical inefficiency as two possible sources of the production variability that characterized Russian agriculture during the last decade. They focused on the estimation of the technical inefficiency of agricultural producers in Russia and the production risk they face. The empirical analysis was conducted using panel data from 1996 to 2001 on 443 large agricultural enterprises from three regions in central, southern and Volga Russia. A production function specification accounting for the effect of inputs on both risk and technical inefficiency was found to describe production technologies of Russian farms more appropriately than the traditional stochastic frontier formulation.

Nchare (2007) analysed the factors influencing the technical efficiency of Arabica coffee farmers in Cameroon. To carry out this analysis, a translog stochastic production frontier function, in which technical inefficiency effects were specified to be functions of socioeconomic variables, was estimated using the maximum-likelihood method. The data used were collected from a sample of 140 farmers during the 2004 crop year. The results obtained showed some increasing returns to scale in coffee production. The mean technical efficiency index was estimated at 0.90, and 32 per cent of the farmers surveyed have technical efficiency indices of less than 0.91. The analysis also revealed that the educational level of the farmer and access to credit are the major socioeconomic variables influencing the farmers' technical efficiency. Finally, the findings proved that further productivity gains linked to the improvement of technical efficiency may still be realized in coffee production in Cameroon.

Kolawole and Ojo (2007) examined the overall efficiency of smallholder croppers in Nigeria with a view to examine the productive efficiency of food crop production in the country. Data were collected from 200 farmers selected using multi-stage sampling technique and analyzed using descriptive statistics, stochastic frontier production and cost function models. The return to scale (RTS) for the production function revealed that the farmers operated in the irrational zone (stage I) of the production surface having RTS of 1.11. The mean technical, allocative and economic efficiency of 0.73, 0.87 and 0.68 respectively were obtained from the data analysis, indicating that the sample farmers were relatively very efficient in allocating their limited resources. The result of the analysis indicated that presence of technical inefficiency and allocative inefficiency had effects in the food crop production as depicted by the significant estimated gamma coefficient of each model, the generalized likelihood ratio test and the predicted technical and allocative efficiencies within the farmers.

Nwachukwui and Onyenweaku (2007) delved into economic efficiency analysis of fadama telfairia farmers in Imo State, Nigeria. Specifically, it identified the production systems; estimated the economic efficiency and their determinants. A multistage random sampling technique was adopted in the selection of 40 fadama telfairia farmers from each of the three agricultural zones of the State. A well-structured questionnaire was used to obtain information on socio-economic characteristics and other relevant variables. Descriptive statistics, which subsume frequencies, means and percentages, were used in the analysis of data on socio-economic characteristics cum production systems. Economic efficiency was analyzed using Translog stochastic profit function. The Maximum Likelihood Estimation Technique was employed in estimating the function while t-test statistic was employed in testing their determinants. With respect to production systems, majority (63.33 %) of Fadama *Telfairia* farmers practiced mixed vegetable production while 36.67 per cent adopted sole Fadama *Telfairia* cropping system. The profit level was influenced by fertilizer price, wage rate and farm size while efficiency was found to be influenced by age, farming experience, membership of cooperative societies, farm and household sizes. The mean economic efficiency was 0.57 and as such, the average Fadama Telfairia would require a cost saving of 42 per cent in order to attain the profit status of the most economically efficient farmer in the sample. Given the fact that ample opportunity exists for improvement in their efficiency, introduction of birth control policies and reviews of Land Use Act of 1990 were among policy options suggested by them.

Chen *et. al* (2009) examined farm level technology and the technical efficiency of farms in China, a country with millions of small farms. They showed that the parameters of the translog stochastic frontier production function were significantly different across regions in China but that the parameters of the technical efficiency function were the same after standardizing the efficiency index. They found that marginal products of land, labour, capital and fertilizer differed significantly across regions, and they were not efficiently allocated. In addition, excessive labor seemed to exist in China's agriculture, leading to a very low marginal product of labour. Even with many small farms, one cannot reject the null hypothesis of a constant return to scale in China's agriculture.

Ozkan *et. al.* (2009) studied the discrepancies between production amount and production values, amounts and values of inputs used and profit ratios of enterprises, even if the enterprises had identical technological constraints. It was not possible to receive identical yields with utilization of equal amount and quality of inputs. There were discrepancies between production amount and production values, amounts and values of inputs used and profit ratios of enterprises, even if the enterprises had identical technological constraints. This depended upon different productive capabilities and less favorable utilization resources by some enterprises. Productive efficiency or economic efficiency was determined as production of maximum amount of outputs by utilizing minimum amount of inputs under a given technological structure. Yet, the determinants of productive efficiency were related with the production process and allocation of resources.

Dodamani *et. al.* (2009) conducted a study, entirely based on a purposive sampling framework by collecting data from 80 farmers contracted for organically cultivating naturally colored cotton variety dharwad desi colored cotton -1 (DDCC-1) from Uppinbetageri village of Dharwad taluk: The study pertained to the agricultural year 2005-06. The resource use efficiency, estimated using the Cobb Douglas production function, revealed that the inputs land (area under colored cotton), seed, farmyard manure and human labour would improve gross returns if their use was further augmented. Similarly bullock labour, bio-pesticides and trichocards would also improve returns but their estimation was not statistically significant. Overall, there was an increasing return to scale. But the marginal value product (MVP) to marginal factor cost (MFC) ratios indicated that except for bullock labour, all other inputs could be profitably increased. The Timmer and Kopp measures of efficiency employed in the study indicated that there was surplus usage of all the resources above the frontier level ranging from 4.65 per cent to 23.75 per cent. Three-fourths of the farmers operated at the 70-80 per cent level of technical efficiency or at an average of 0.76 technical efficiency. The allocative efficiency was 0.585 while the economic efficiency was 0.443.

Alemu *et. al.* (2009) tried to fill the gap by investigating efficiency variations and factors causing (in) efficiency across agro-ecological zones in East Gojjam, Ethiopia. Data were collected from 254 randomly selected households. Stochastic frontier production function was estimated and the results of the analysis revealed a mean technical efficiency of 75.68 per cent (ranging from 32.15 per cent to 92.66 per cent). F-test also showed a statistically significant difference in technical efficiency among agro-ecological zones with highland zones scoring the highest leading to a rejection of the hypothesis of no significant efficiency difference. On the other hand, maximum likelihood estimates indicated positive and significant elasticities for inputs such as land, labour, draft power and fertilizer. Besides education, proximity to markets and access to credit were found to reduce inefficiency levels significantly. However, neither extension visits nor trainings on farmland management brought positive impacts in affecting the efficiency level of farmers. Thus, future endeavours might need to find ways to envisage better extension services provisions that were tailored to the peculiarities of the agro-ecological zones. Last but not least, improved market outlets and reduced liquidity constraints should be considered to change things for the better.

Omonona *et. al.* (2010) presented a paper on the analysis of technical efficiency of cowpea production in Osun state southwest Nigeria, using the stochastic production frontier, budgetary and resource-use efficiency analyses. The marginal value products of all the resources used were less than their prices, indicating underutilization of resources. The enterprise economic efficiency was 1.17. The farmers' average technical efficiency was 87 per cent, which suggested an appreciable use of inputs in productivity. Analysis efficiency using stochastic production frontier showed that farm size, seed, hired labour, family labour, fertilizer and pesticides were significant at one per cent and some socio-economic variables using Tobit regression model were found to be significantly different from zero at one per cent for cooperative membership and farming experience. It was recommended that farmers should be encouraged to join cooperative society and extension services agents should intensify their efforts in training and mobilizing farmers for improved production of cowpea. Also, farmers should cut down the use of resources (quantity) for optimum production and economic benefit.

Agbonlahor (2010) evaluated technical efficiencies in the sawmilling sector. Specifically, the main objective of the study was to assess technical efficiency dispersion and determine the significant, firm specific, factors that caused technical inefficiencies in sawmilling operations. Maximum-likelihood methods were applied in the estimation of the parameters of the model. In the study, panel (3 years) data from 68 sawmills were used in the empirical analysis. The primary decision-maker in the sawmill had an average age of 53years with a mean of 17years of experience in sawmill management. The average operational age of the sawmill was 13 years.

There were considerable wide variations, at the firm level, in technical efficiencies recorded over the periods. The estimated average technical efficiency of the sampled sawmills for the three years (2007-2009) was 61.9 per cent. The result revealed that the initial efficiency gained in 2007 was not sustained as efficiency dropped in 2009 to 57.9 per cent. The firm specific variables that influenced technical efficiencies were owner's status as timber contractor, ownership of timber trucks, years of experience and age of the manager. The study recommended that technical and management training/workshop should be organized by relevant government agencies to regularly update operators' knowledge. Import policies should be targeted to encourage acquisition and use of modern sawmilling machines and equipment. Also, public power supply to the sawmill clusters should be improved to reduce the high processing cost associated with the use of diesel powered electricity generation sets.

Shehu *et. al.* (2010) investigated the determinants of yam production and technical efficiency of yam farmers using stochastic frontier production function, which incorporated a model of inefficiency effects. Farm-level data were collected from a sample of 100 yam farmers in Benue State using structured questionnaires. The empirical results indicated that land, seed yam, family labour and fertilizer were the major factors that influenced changes in yam output. Farmer-specific variables such as education, membership of association and household size were found to have significant effects on the observed variation in technical efficiency among the yam producers. The technical efficiency of farmers varied from 0.67 to 0.99 with a mean of 0.95. The implication of the study was that efficiency in yam production among the farmers could be increased by 5 per cent through better use of land, seed yam, family labour and fertilizer in the short term given the prevailing state of technology. This could be achieved through policy interventions that would contribute to better access to land, improved seed and fertilizer as well as provision of labour saving technologies to ease farm operations. Also, improved farmer's educational levels through adult education and literacy campaign would probably increase efficiency in the long term.

Wakili (2012) investigated the technical efficiency of sorghum production and its determinants, using the stochastic frontier production function which incorporated a model of inefficiency effects. Farm level data were collected from a sample of 100 sorghum farmers in Hong local government area of Adamawa state using structured questionnaires. The empirical result showed that land, seed, and fertilizer were the major factors that influenced changes in sorghum output. Farm specific variables such as education, extension contact and household size were found to have significant effects on the technical inefficiency among the sorghum producers. The technical efficiency of farmers varied from 0.16 to 0.92 with a mean technical efficiency of 0.73. The implication of the study was that efficiency in sorghum production among the farmers could be increased by 28 per cent through better use of land, seed and fertilizer in the short term, given the prevailing state of technology. This could be achieved through policy interventions by the government in terms of better access to land, improved seed, fertilizer. The inefficiency effect also showed that improved farmer's educational levels through better education, and literacy campaigns would help tremendously to increase efficiency.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Data collected as the part of the research project "Survey on Assessment of Productivity and Production Constraints of Major Spices of Kerala, 2008-2011.", conducted by the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara was used for the study. The data include area of holdings, number of vines, yield, expenses for machinary, labour, manure and other expenses for the cultivation of pepper.

3.1. AREA OF STUDY

The data pertaining to pepper cultivation was collected from Mananthavady. Kalpetta and Bathery blocks of Wayanad district.

3.1.1. Wayanad district

Wayanad district is situated in the northeast coast of India. The district is bounded on the east by Nilgiris and Mysore districts of Tamilnadu and Karnataka respectively, on the north by Coorg district of Karnataka, on the south by Malappuram and on the west by Kozhikode and Kannur. It lies between north latitude 110 27′ and 150 58′ and east longitude 750 47‘and 700 27′. The altitude of Wayanad varies from 700 to 2300 meters from sea level.

Wayanad has a salubrious climate. The mean average rainfall in this district is 2322 mm. Lakkidi, Vythiri and Meppadi are the high rainfall areas in Wayanad. Annual rainfall in these high rainfall areas ranges from 3,000 to 4,000mm. High velocity winds are common during the southwest monsoon and dry winds blow in March-April. High altitude regions experience severe cold. In Wayanad (Ambalavayal) the mean maximum and minimum temperature for the last five years were 29°C and 18°C respectively. This place experiences a high relative humidity, which goes even up to 95 per cent during the southwest monsoon period. During the hot weather the temperature goes up to a maximum of 35°C (95°F) and during the cold weather the temperature goes down to 7°C (45°F).

The total geographical area and population of Wayanad are 2126 sq.kms, (2,12,560 hectares) and 8,16,558 respectively, which account for 5.48 per cent and 2.31 per cent of the state total.

For the smooth running of the revenue administration, the district is divided in to three taluks, viz; Sulthan Bathery, Vythiri and Mananthavady. There are four Block Panchayats and 49 villages under these taluks. There is only one Revenue Divisional Office in this district that is functioning at Mananthavady.

3.1.2. Mananthavady Block Panchayat

Mananthavady is located 35 km northeast of the district headquarters Kalpetta, 80 km east of Thalassery and 110 km northeast of Kozhikode. Thalassery-Bavali Road is the major road passing through Mananthavady, which is well connected with both Mysore and Kodagu.

3.1.3. Sulthan Bathery Block Panchayat

Sulthan Bathery is a town in Wayanad district of Kerala, India. This town was part of Kidanganadu Village. This town is the largest town in Wayanad District.

Sulthan Bathery is situated at about 930 meters above mean sea level. One can find beautiful folded hills across the horizon. The climate is pleasant throughout the year. The town is the centre of tourism in Wayanad District.

3.1.4. Kalpetta Block Panchayat

Kalpetta is a town and a municipality in Wayanad district. This small town surrounded by dense coffee plantations and mountains, is the headquarters of Wayanad district. It lies on the Kozhikode-Mysore National Highway (NH 212) at an altitude of about 780 m above sea level. Kalpetta is 72km from Kozhikode and 140km from Mysore. Apart from the administrative capital of the district, Kalpetta is also the center of tourism activities in Wayanad due to its central location within the district.

3.2. Estimation methods

3.2.1. Maximum Likelihood Method

The principle of maximum likelihood is relatively straightforward. A sample X = (x_1, x_2, ..., x_n) of random variables is chosen according to one of a family of probabilities P_θ. In addition, $f(x/\theta)$, X = (x_1, x_2, ..., x_n) will be used to denote the density function for the data when θ is the true state of nature.

This yields a choice of the estimator $\hat{\theta}$ as the value for the parameter that makes the observed data most probable.

The likelihood function is the density function regarded as a function of θ.

$$L(\theta/x) = f(x/\theta);\ \theta \in \Theta \qquad \ldots (1)$$

The Maximum Likelihood Estimator (MLE), $\hat{\theta}(x) = \max L(\theta/x)$ ... (2)

The estimator has an important property. If $\hat{\theta}$ (x) is a maximum likelihood estimate for θ, then g ($\hat{\theta}$(x)) is a maximum likelihood estimate for g (θ). For example, if θ is a parameter for the variance and $\hat{\theta}$ is the maximum likelihood estimator, then $\sqrt{\hat{\theta}}$ is the maximum likelihood estimator for the standard deviation. This flexibility in estimation criterion seen here is not available in the case of unbiased estimators (Gujarati, 2003).

3.2.2. Present value

When data is collected through a rapid estimation survey only the present cost (PC) of production at each stage of growth of the crop will be available. For a pepper holding which is in the steady bearing stage or in any advanced stages, the exact costs involved at the previous stage of growth will be comparatively lesser. So a methodology has to be evolved to assess at the various stages of a growth of a holdings which is already in an advanced stage of growth. So for the estimation of exact cost, the concept of present value (PV) is adopted (clutter *et. al.*, 1983).

Present value of any cost involved is estimated as $PV = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t}$

Where

C_t: present cost in the period t

n : number of years involved

i : discount rate

The overhead costs involved for establishment of a farm up to its bearing stage as also full yielding stage was estimated using the above formula using a discount rate 10 %. *Total cost* $= \frac{AG_4}{(1+0.1)^0} + \frac{AG_3}{(1+0.1)^3} + \frac{AG_2}{(1+0.1)^5} + \frac{AG_1}{(1+0.1)^8}$.

Here AG4, AG3, AG2, and AG1 are the present costs for different stages and $\frac{AG_4}{(1+0.1)^0}, \frac{AG_3}{(1+0.1)^3}, \frac{AG_2}{(1+0.1)^5}$ and $\frac{AG_1}{(1+0.1)^8}$ are the present values for different stages.

The costs involved at the full bearing stage are taken as such. All the costs involved are estimated on a per vine basis. For all the farms in all the age group in a block, the respective overhead costs are worked out on a per vine basis. All the overhead costs of a farm are estimated based on the number of vines.

3.2.3. One-way analysis of variance

In statistics, one-way analysis of variance (ANOVA) is a technique used to compare means of two or more samples (using the F distribution). This technique can be used only for numerical data. The ANOVA produces an F-statistic, the ratio of the variance calculated among the means to the variance within the samples. If the group means are drawn from populations with the same mean values, the variance between the group means should be lower than the variance of the samples, following the central limit theorem. A higher ratio therefore implies that the samples are drawn from populations with different mean values (Das and Giri, 1986).

3.2.4. Regression equation

It is a statistical procedure used to find relationships among a set of variables. In regression analysis, there is a dependent variable and one or more independent variables that are related to it.

Regression is the attempt to explain the variation in a dependent variable using the variation in independent variables. Regression is thus an explanation of causation (Gujarati, 2003).

If the independent variable(s) sufficiently explain the variation in the dependent variable, the model can be used for prediction. The output of a regression is a function that predicts the dependent variable based upon values of the independent variables. The regression equation is

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon$$

Where Y is the dependent variable

β_o is the intercept term

β_i is the regression coefficient for the i^{th} independent variable; ($i = 1, 2, \ldots, n$)

and ε is the error term

3.2.5. Production frontier

In this model, technical efficiency is defined as the firm's ability to produce maximum output given a set of inputs and technology. Stated differently, technical inefficiency reflects the failure of attaining the highest possible level of output for given input and technology. In contrast, Allocative (or price) Efficiency measures the firm's success in choosing the optimal input proportions, i.e., where the ratio of marginal products for each pair of inputs is equal to the ratio of their market prices.

In Farrell's framework, economic efficiency is a measure of overall performance and is equal to TE times AE. A large number of frontier models have been developed. They are based on Farrell's work and can be classified into two basic types; parametric and non-parametric. Parametric frontiers rely on a specific functional form while non-parametric frontiers do not. Due to the data limitations, the parametric approach is followed. Another important distinction is between deterministic and stochastic frontier. The deterministic model assumes that any deviation from the frontier is due to inefficiency. The deterministic parametric approach was initiated by Aigner and Chu (1968) who estimated a Cobb-Douglas production frontier through linear and quadratic programming techniques.

In contrast, the stochastic approach allows for statistics noise. This is the option that we pursue given the prevailing ignorance about actual agricultural technical processes. In the stochastic production frontier, technical efficiency is measured with one-sided disturbance term. When explicit assumptions for the distribution of the disturbance term are introduced, the frontier function can be estimated using the maximum likelihood method. If no assumptions are made concerning the distribution of the error term, the frontier can also be estimated by the COLS which consist of shifting the intercept term of the frontier function upwards until no positive error term remains.

3.2.6. Stochastic frontier production functions

The modeling, estimation and application of stochastic frontier production function to economic analysis assumed prominence in econometrics and applied economic analysis following Farrell's (1957) findings where he introduced a methodology to measure technical, allocative and economic efficiency of a firm. According to Farrell, TE is associated with the ability of a firm to produce on the isoquant frontier while Bravo and Pinheiro refers to AE as the ability of a firm to produce at a given level of output using the cost minimizing input ratios, thus defining EE as the capacity of a firm to produce a predetermined quantity output at a minimum cost for a given level of technology (Bravo and Pinheiro, 1997).

However, over the years, Farrell's methodology had been applied widely, while undergoing many refinements and improvements. One of such improvement is the development of stochastic frontier model which enables one to measure firm level technical and economic efficiency using maximum likelihood estimate COLS. Aigner *et. al.* (1977) and Meeusen and Broeck (1977) were first to propose stochastic frontier production function and since then many modifications have been made to stochastic frontier analysis. Aigner *et. al.* (1977) applied the stochastic frontier production function in the analysis of the U.S agricultural data. Battese and Corra (1977) applied the technique to the pastoral zone of eastern Australia. In Meeusen and Broeck (1977) application, the technique was applied to the analysis of ten French manufacturing industries. More recently, empirical analyses have been reported by Battese *et. al.* (1993) and Ojo (2004).

3.2.7. Model specification

The stochastic frontier production function of Cobb-Douglas functional form is employed to estimate the firm-level technical and allocative efficiencies of the farmers in the study areas. The Cobb-Douglas Functional form was used because: the functional form has been widely used in farm efficiency for the developing and developed countries, the functional form meets the requirement of being self-dual, allowing an examination of economic efficiency and lastly Kopp and Smith (1980) suggested that functional form has limited effects on empirical efficiency measurement.

The Cobb-Douglas production functional form which specifies the production technology of the farmers is expressed as follows:

$$Y_i = f(Xi; \beta) \exp(V_i - U_i) \quad \ldots \quad (1)$$

Where Y_i represents the value of output, which is measured in number (Number); X_i represents the quantity of input used in the production. The V_i's are assumed to be independently and identically distributed random errors, having normal $N(0, \sigma_v^2)$ distribution and independent of the U_i's. The U_i's are technical inefficiency effects, which are assumed to be non-negative truncation of the half-normal distribution $N(\mu, \sigma_u^2)$.

The technical efficiency of individual farmers is defined in terms of the ratio of observed output to the corresponding frontiers output, conditional on the level of input used by the farmers. Hence the technical efficiency of the farmer is expressed as:

$$TE_i = Y_i / Y_i^* = f(X_i; \beta) \exp(V_i - U_i) / f(X_i; \beta) \exp V_i = \exp(-Ui) \ldots (2)$$

Where: Y_i is the observed output and Y_i^* is the frontiers output. The TE ranges between zero and one.

The corresponding cost frontier of Cobb - Douglas functional form which is the basis of estimating the allocative efficiencies of the farmers is specified as follows:

$C_i = g\ (P_i;\ \alpha)\ exp\ (V_i + U_i);\ = 1, 2, ..., n$ ... (3)

Where C_i represents the total input cost of the i^{th} farm; g is a suitable function such as the Cobb-Douglas function; P_i represents input prices employed by the i^{th} farm in food crop production and measured in naira; α is the parameter to be estimated, V_i's and U_i's are random errors and assumed to be independent and identically distributed truncations (at zero) of the $N\ (\mu,\ \sigma^2)$ distribution. U_i provides information on the level of allocative efficiency of the i^{th} farm. The allocative efficiency of individual farmers is defined in terms of the ratio of the predicted minimum cost (C_i*) to observed cost (C_i).

That is: $AE_i = C_i^*/C_i = exp\ (U_i)$ ... (4)

Hence, allocative efficiency ranges between zero and one.

3.2.8. Method of data analysis

Descriptive statistics viz; mean and standard deviations are used to assess socio-economic characteristics, stochastic frontier production and cost functions are used to analyse the technical and allocative efficiency respectively of farms. While the farmer's economic efficiencies are estimated as the product of TE and AE, the production technology of the farmers is assumed to be specified by the Cobb-Douglas frontier production function which is defined by;

$In\ Y_i = In\ \beta_0 + \beta_1\ In\ X_{1i} + \beta_2\ In\ X_{2i} + \beta_3\ In\ X_{3i} + \beta_4\ In\ X_{4i} + \beta_5\ In\ X_{5i} + \beta_6\ In\ X_{6i} + (V_i - U_i)$ ... (5)

Where Y = total output (kg)

X_1 = area of holdings (ha)

X_2 = number of vines (N)

X_3 = cost of machinary (Rs)

X_4 = cost of labour (Rs)

X_5 = cost of manure (Rs)

X_6 = other expenses (Rs)

The variances of the random errors, σ_v^2 and that of the technical and allocative inefficiency effects σ_u^2 and overall variance of the model σ^2 are related thus: $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and the ratio $\gamma = \sigma_u^2 / \sigma^2$, measures the total variation of output from the frontier which can be attributed to technical or allocative inefficiency (Battese and Corra, 1977). The estimates for all the parameters of the stochastic frontier production function and the inefficiency model are simultaneously obtained using the program *FRONTIER version 4.1c* (Coelli, 1996).

3.2.9. Technical efficiency: the concept and basic model

While the concept of technical efficiency is as old as neoclassical economics, interest in its measurement is not. This is probably explained by the fact that neoclassical production theory presupposes full technical efficiency. Then, the question raises as to why, one should measure technical efficiency. There are two principal arguments for its measurement. The first and most compelling reason lies in the recognition that a gap exists between the theoretical assumption of full technical efficiency and empirical reality. Leibenstein (1966) drew attention to this in the sixties. Second, on a priori reasoning, there is a high probability that, where technical inefficiency exists, it will exert an influence on allocative efficiency and that there will be a cumulative negative effect on economic efficiency (Bauer, 1990). Following this logic, technical efficiency becomes central to the achievement of high levels of economic performance at the firm level, as does its measurement.

The basic concept underpinning the measurement of technical efficiency starts with the description of production technology. Production technologies can be represented using isoquant, production functions, and cost functions or profit functions. These four models provide four different tools for measuring technical efficiency. Although analyses based on these models appear to be distinct, they constitute the same basic approach and ideally, their results should converge.

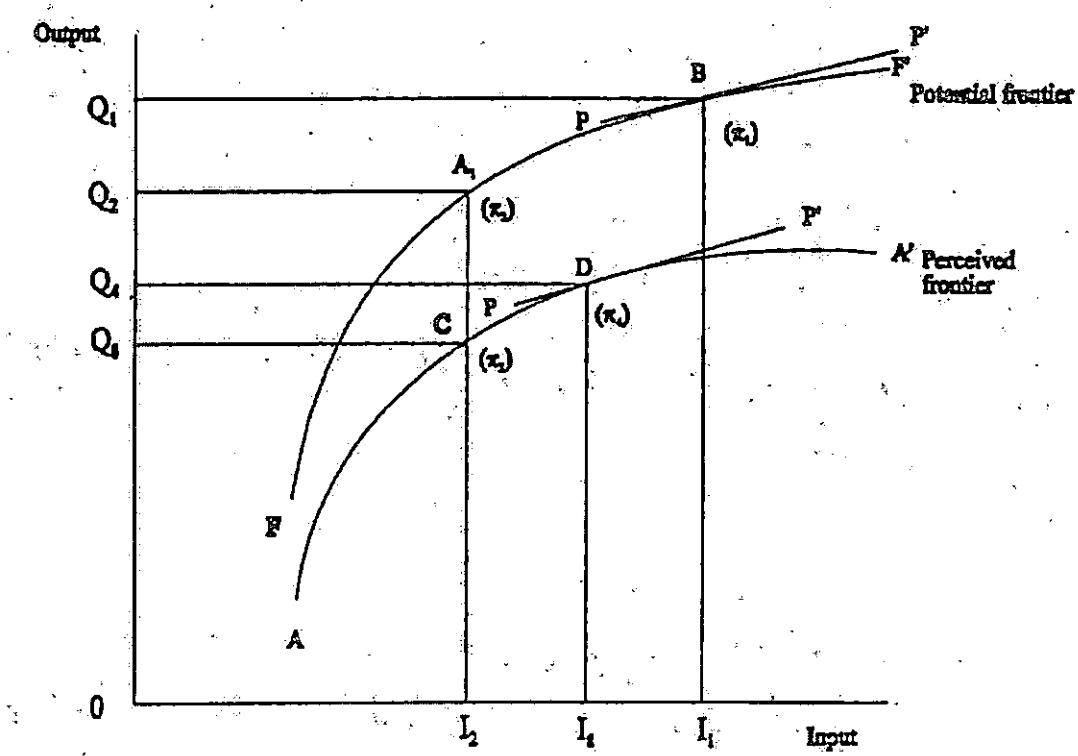


Figure 1.1. The concepts of firm-specific technical efficiency, allocative efficiency and economic efficiency

Note: Figures in parentheses refer to net profits associated with concerned inputs and technology.

It has been acknowledged in the literature that, in reality, a gap normally exists between a firm's actual and potential levels of technical performance. This carries conceptual implications for the understanding of measurement of efficiencies, which can be understood with the help of figure 1.1.

In neoclassical theory, all firms operate at potential technical efficiency, at points along the frontier *FF'*. Any inefficiency will be solely allocative. Thus, if a firm is operating on its frontier *FF'*, its point of economic efficiency may be at *B'* the point of tangency with its price line. If it operates at *B*, with input I_1 and output Q_1 there will be maximum profit π_1 and no allocative or economic inefficiency. It should be noted that, provided firms are operating on their technical frontiers, allocative (in) efficiency will be the same as economic (in) efficiency (they are used synonymously in the literature) because of the theoretical assumption of potential technical efficiency. Thus if a firm is operating at point A on its frontier, using I_2 input and producing Q_2 output its profits may be π_2, and its allocative/economic inefficiency will be measured as π_2/π_1.

In practice, with a new technology, firms operate at less than potential technical efficiency owing to incomplete knowledge of best technical practices or to other organizational factors that prevent it from operating on its technical frontier. Thus, a firm will operate on an actual or perceived production function which is below the potential frontier, e.g. on *AA'* in Figure l. At I_2 input, it operates at point *C*, produces Q_3 output and earns π_3 profit. On this actual production function, point C is allocatively inefficient. To maximize its profit (π_4) it would have to operate at point *D*, use I_3 input and produce Q_4 output. At *D*, however, it would not achieve potential economic efficiency, for by definition, potential economic efficiency can only be achieved with potential technical efficiency.

To be consistent with neoclassical production theory, efficiency should only be measured in relation to the frontier production function *FF'*. Thus if a firm is operating at *C* on its actual or perceived production function, its economic inefficiency would be measured in profit terms by the ratio π_2/π_1, or in output terms by the ratio Q_2/Q_1.

Now, it can easily be seen in Figure I that this economic inefficiency comprises two components, technical and allocative inefficiencies. In profit terms, the total loss in economic inefficiency in operating at point C is $\pi_1 - \pi_3$. Of this, the loss from technical inefficiency is $\pi_3 - \pi_2$, and the loss due to allocative inefficiency is $\pi_1 - \pi_2$. In output terms, the losses are $Q_2 - Q_3$ and $Q_1 - Q_2$ respectively.

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results of the study "Formation and efficient estimation of stochastic frontier production function" are presented as follows.

4.1. Summary statistics

The summary statistics of various parameters namely area of holdings (acre), number of vines in different age groups, expenses for machinary (Rs.), labour (Rs.), manure (Rs.), other expenses (Rs.) and yield (kg.) of pepper for the four age groups (Fresh planting, 2-3 years of planting, 3-7 years of planting and 8 years and above) in the three blocks viz; Mananthavady, Kalpetta and Bathery were calculated.

4.1.1. Mananthavady

4.1.1.1. First age group

The area of holdings under fresh planting ranged from 0.5 to 40 acres with a mean of 7.61 acres. Accordingly, the number of vines ranged from 70 to 800. The mean expense for machinary was Rs. 399 with a maximum cost of Rs. 1125. The mean cost of labour was Rs. 15383 with a range of Rs. 1650 to Rs. 66550. The mean manure cost was Rs. 1730 with a minimum cost of Rs. 250 and a maximum cost of Rs. 4100. A maximum of Rs. 8745 was incurred towards other expenditure with a mean cost of Rs. 3340 (Table 4.1.1.1).

4.1.1.2. Second age group

The second age group (2 to 3 years) had the area of holdings ranging from 2.5 to 40 acres with a mean of 9.22 acres. The number of vines ranged from 200 to 400 with a mean of 282. A maximum cost of Rs. 1863 was incurred towards expenses for machinary with a mean cost of Rs. 819. The labour cost ranged from Rs. 9500 to Rs. 25850 with a mean cost of Rs. 15582. The mean manure cost was Rs. 4695 with a

Table 4.1.1.1. Descriptive statistics for fresh planting in Mananthavady block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	0.50	40.00	7.61	11.81
No. of Vines	70.00	800.00	324.50	216.03
Machinary (Rs.)	0.00	1125.00	398.73	419.50
Labour (Rs.)	1650.00	66550.00	15382.50	19432.76
Manure (Rs.)	250.00	4100.00	1730.00	1315.76
Other expenses (Rs.)	0.00	8745.00	3339.50	2534.64

Table 4.1.1.2. Descriptive statistics for two to three years old planting in Mananthavady block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	2.50	40.00	9.22	11.27
No. of Vines	200.00	400.00	282.00	64.26
Machinary (Rs.)	100.00	1862.50	811.88	572.84
Labour (Rs.)	9500.00	25850.00	15582.50	5699.27
Manure (Rs.)	0.00	15000.00	4695.00	5026.23
Other expenses (Rs.)	420.00	3100.00	1215.00	749.33

maximum cost of Rs. 15000. A maximum cost of Rs. 3100 was incurred towards other expenditure with a mean cost of Rs. 1215 (Table 4.1.1.2).

4.1.1.3. Third age group

The third age group (3 to 7 years) had the area of holdings ranging from 1.45 to 10 acres with a mean of 5.17 acres. The number of vines ranged from 200 to 600 with a mean of 362. A maximum cost of Rs. 1750 was incurred towards expenses for machinary with a mean cost of Rs. 911. The labour cost ranged from Rs.17100 to Rs. 102450 with a mean cost of Rs. 41044.50. The mean manure cost was Rs. 6070 with a maximum cost of Rs. 12000. A maximum of Rs. 15325 was incurred towards other expenditure with a mean cost of Rs. 5609.50. The third age group started yielding with a maximum yield of 2200 kg. and a minimum yield of 245 kg., with a mean yield of 1035 kg (Table 4.1.1.3).

4.1.1.4. Fourth age group

The fourth age group (8 years and above) was in the full yielding stage and had a maximum yield of 800 kg. and a minimum yield of 200 kg. with a mean yield of 374.5 kg. The area of holdings ranged from one to 40 acres with the mean of 8.64 acres and the number of vines ranged from 50 to 150 with a mean of 90. The mean expense for machinary was Rs. 592 with a minimum cost of Rs. 63 and a maximum cost of Rs. 1250. The labour cost ranged from Rs.7100 to Rs. 18350 with a mean cost of Rs. 14067.50. The mean manure cost was Rs. 1905 with a maximum cost of Rs. 4400. A maximum of Rs. 2500 was incurred towards other expenditure with a mean cost of Rs. 1250 (Table 4.1.1.4).

Table 4.1.1.3. Descriptive statistics for four to seven years old planting in Mananthavady block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	1.45	10.00	5.17	3.24
No. of Vines	200.00	600.00	362.00	125.59
Machinary (Rs.)	250.00	1750.00	910.62	539.37
Labour (Rs.)	17100.00	102450.00	41044.50	26103.19
Manure (Rs.)	1600.00	12000.00	6070.00	3388.31
Other expenses (Rs.)	1125.00	15325.00	5609.50	4654.27
Yield (kg.)	245.00	2200.00	1035.00	723.11

Table 4.1.1.4. Descriptive statistics for eight years old and above planting in Mananthavady block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	1.00	40.00	8.64	11.82
No. of Vines	50.00	150.00	90.00	31.18
Machinary (Rs.)	62.50	1250.00	591.88	353.04
Labour (Rs.)	7100.00	18350.00	14067.50	3487.16
Manure (Rs.)	500.00	4400.00	1905.00	1313.91
Other expenses (Rs.)	0.00	2500.00	1250.00	774.70
Yield (kg.)	200.00	800.00	374.50	173.12

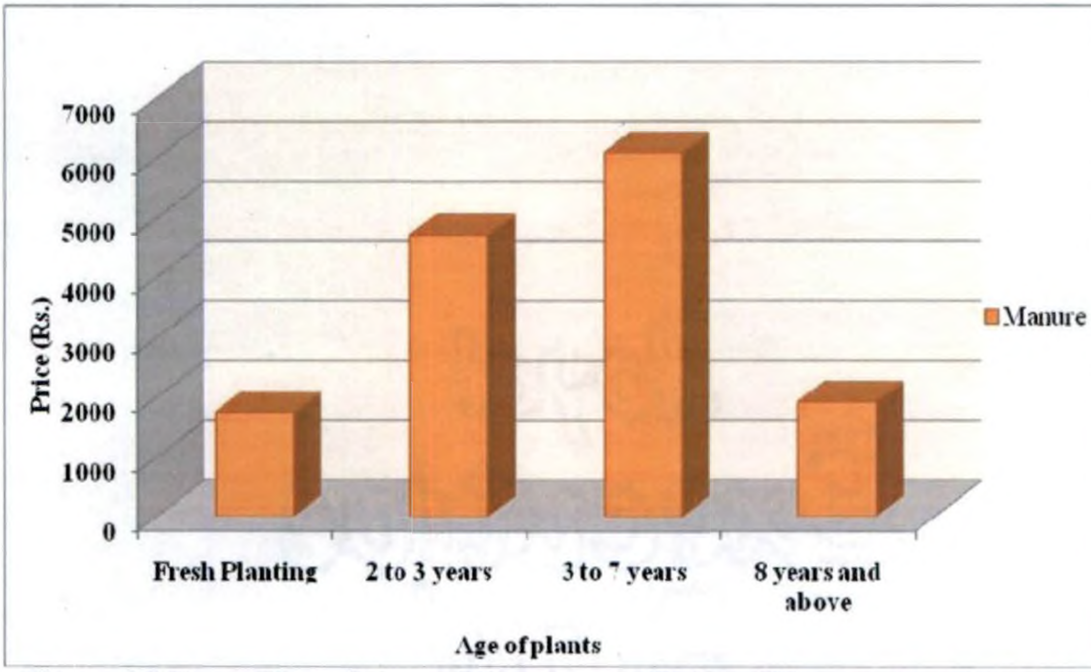


Figure 2.1 Expenditure incurred for manure (Rs.) at different ages of pepper plantation in Mananthavady block

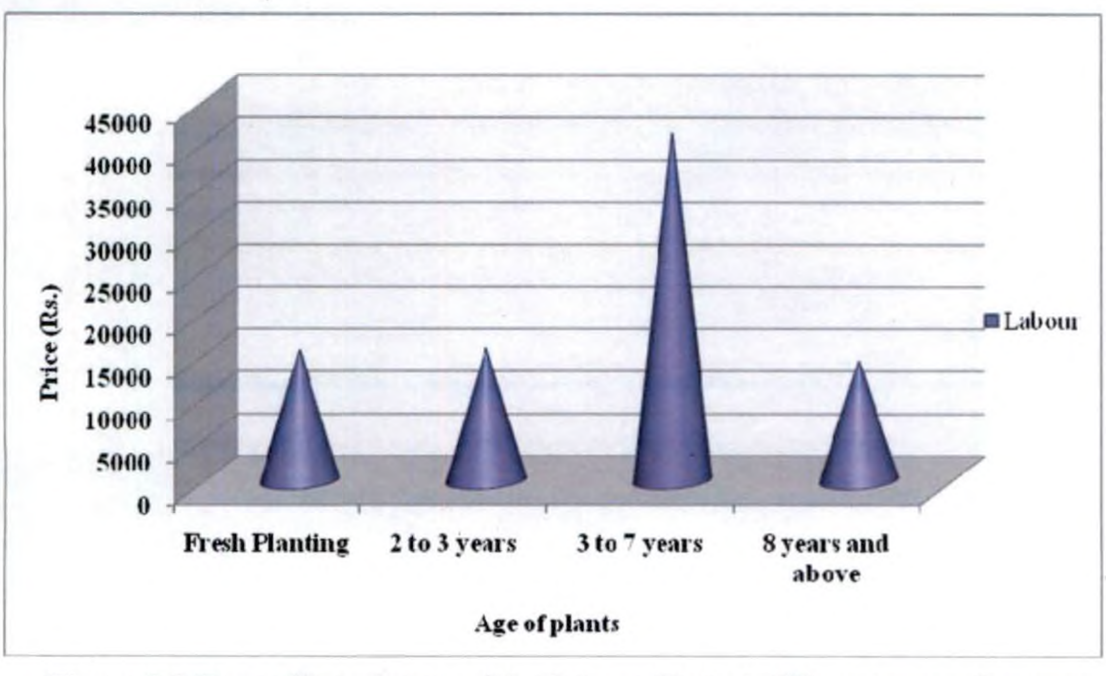


Figure 2.2 Expenditure incurred for labour (Rs.) at different ages of pepper plantation in Mananthavady block

4.1.2.1. First age group

The area of holdings under fresh planting ranged from 0.4 to 3 acres with a mean of 1.69 acres. Accordingly, the number of vines ranged from 150 to 1080. The mean expense for machinary was Rs. 789 with a minimum cost of Rs. 100 and a maximum cost of Rs. 3100. The mean cost of labour was Rs. 6260 with a maximum cost of Rs. 20,000. The mean manure cost was Rs. 1302 with a maximum cost of Rs. 4000. A maximum of Rs. 13700 was incurred towards other expenditure with a mean cost of Rs. 2680 (Table 4.1.2.1).

4.1.2.2. Second age group

The second age group (2 to 3 years) had the area of holdings ranging from 0.5 to 2 acres with a mean of 0.935 acres. The number of vines ranged from 150 to 600 with a mean of 295. The mean expense for machinary was Rs. 168 with a minimum cost of Rs. 75 and a maximum cost of Rs. 450. The labour cost ranged from Rs. 4000 to Rs. 16600 with a mean cost of Rs. 8890. The mean manure cost was Rs. 1990 with a minimum cost of Rs. 1200. A maximum of Rs. 400 was incurred towards other expenditure with a mean cost of Rs. 265 (Table 4.1.2.2).

4.1.2.3. Third age group

The third age group (3 to 7 years) had the area of holdings ranging from 0.5 to 3 acres with a mean of 1.34 acres. The number of vines ranged from 100 to 400 with a mean of 240. The mean expense for machinary was Rs. 446 with a minimum cost of Rs. 50 and a maximum cost of Rs. 1136. The labour cost ranged from Rs.5900 to Rs. 18200 with a mean cost of Rs. 11760. The mean manure cost was Rs. 3135 with a maximum cost of Rs. 5700. A maximum of Rs. 825 was incurred towards other expenditure with a mean cost of Rs. 365. This age group started yielding with a maximum yield of 600 kg. and a minimum yield of 50 kg, the mean yield being 193 kg (Table 4.1.2.3).

Table 4.1.2.1. Descriptive statistics for fresh planting in Kalpetta block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	0.40	3.00	1.69	0.93
No. of Vines	150.00	1080.00	401.00	267.97
Machinary (Rs.)	100.00	3100.00	788.75	914.93
Labour (Rs.)	0.00	20000.00	6260.00	6775.23
Manure (Rs.)	0.00	4000.00	1302.00	1216.75
Other expenses (Rs.)	0.00	13700.00	2680.00	4103.87

Table 4.1.2.2. Descriptive statistics for two to three years old planting in Kalpetta block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	0.50	2.00	0.94	0.42
No. of Vines	150.00	600.00	295.00	121.22
Machinary (Rs.)	75.00	450.00	167.50	105.44
Labour (Rs.)	4000.00	16600.00	8890.00	3363.02
Manure (Rs.)	1200.00	3600.00	1990.00	743.42
Other expenses (Rs.)	100.00	400.00	265.00	94.43

4.1.2.4. Fourth age group

The fourth age group (8 years and above) was in the full yielding stage and the area of holdings ranged from 0.5 to 3 acres with a mean of 1.43 acres. The number of vines ranged from 200 to 400 with a mean of 300. The mean expense for machinary was Rs. 576 with a minimum cost of Rs. 50 and a maximum cost of Rs. 2438. The labour cost ranged from Rs.9600 to Rs. 19800 with a mean cost of Rs. 15115. The mean manure cost was Rs. 4370 with a maximum cost of Rs. 6300. A maximum of Rs. 600 was incurred towards other expenditure with a mean cost of Rs. 290. The yield ranged from 100 kg. to 400 kg. with a mean yield of 260 kg (Table 4.1.2.4).

Table 4.1.2.3. Descriptive statistics for four to seven years old planting in Kalpetta block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	0.50	3.00	1.34	0.88
No. of Vines	100.00	400.00	240.00	107.50
Machinary (Rs.)	50.00	1136.00	446.35	307.03
Labour (Rs.)	5900.00	18200.00	11760.00	4288.54
Manure (Rs.)	1250.00	5700.00	3135.00	1483.62
Other expenses (Rs.)	100.00	825.00	365.10	234.80
Yield (kg.)	50.00	600.00	193.00	160.35

Table 4.1.2.4. Descriptive statistics for eight years old and above planting in Kalpetta block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	0.50	2.50	1.43	0.76
No. of Vines	200.00	400.00	300.00	94.28
Machinary (Rs.)	50.00	2437.50	576.25	834.43
Labour (Rs.)	9600.00	19800.00	15115.00	3968.07
Manure (Rs.)	2500.00	6300.00	4370.00	1398.45
Other expenses (Rs.)	0.00	600.00	290.00	181.89
Yield (kg.)	100.00	400.00	260.00	93.69

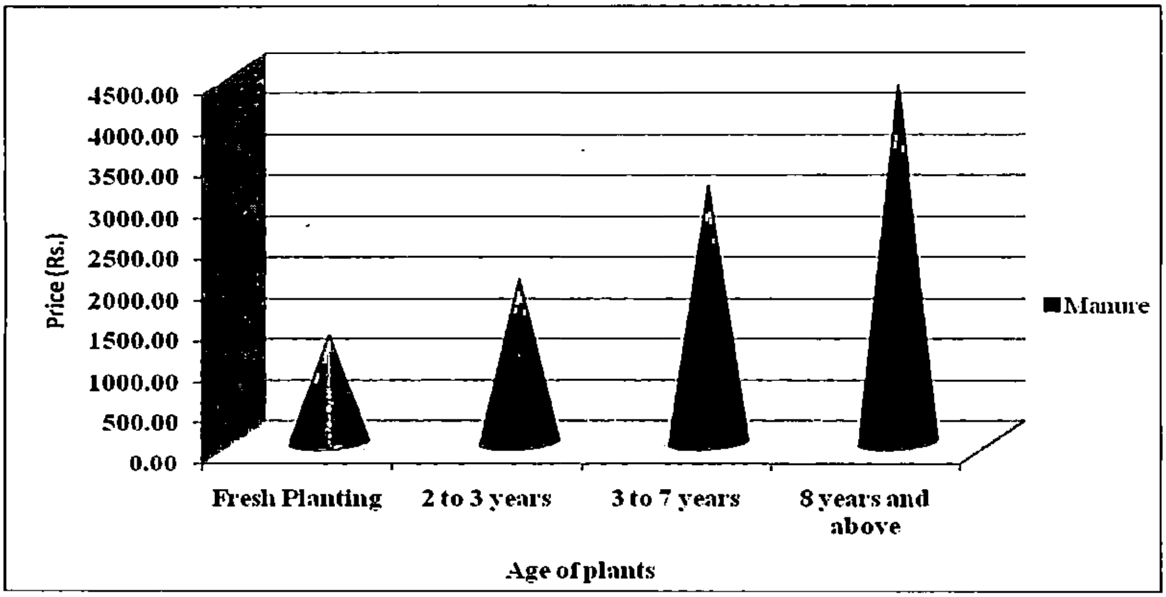


Figure 2.3 Expenditure incurred for manure (Rs.) at different ages of pepper plantation in Kalpetta block

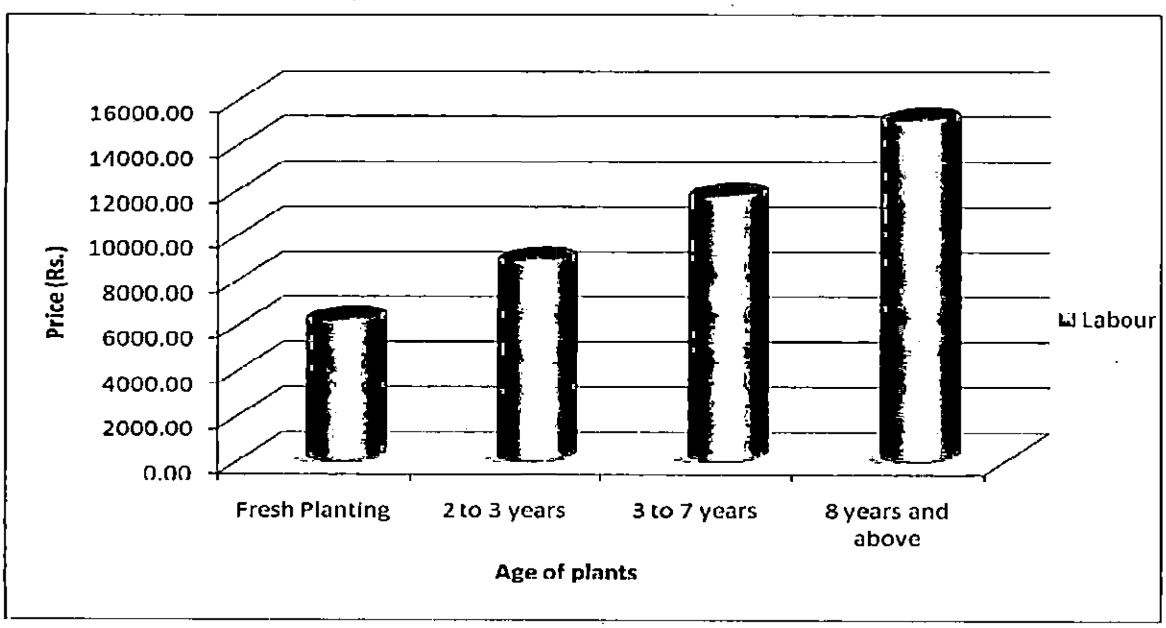


Figure 2.4 Expenditure incurred for labour (Rs.) at different ages of pepper plantation in Kalpetta block

4.1.3. Bathery

4.1.3.1. First age group

The area of holdings under fresh planting ranged from one to six acres with a mean of 2.5 acres. The number of vines ranged from 200 to 600. The mean expense for machinary was Rs. 1211 with a maximum cost of Rs. 3313. The mean cost of labour was Rs. 13,282 with a maximum cost of Rs. 34,900. The mean manure cost was Rs. 2070 with a minimum cost of Rs. 400 and a maximum cost of Rs. 4000. A maximum of Rs. 19200 was incurred towards other expenditure with the mean cost of Rs. 5710 (Table 4.1.3.1).

4.1.3.2. Third age group

The third age group (3 to 7 years) had the area of holdings ranging from 0.5 to five acres with the mean of 2.4 acres and the number of vines ranged from 50 to 2000 with a mean of 540. The mean expense for machinary was Rs. 661 with a maximum cost of Rs. 3275. The labour cost ranged from Rs.10800 to Rs. 23100 with a mean cost of Rs. 18950. The mean manure cost was Rs. 5420 with a maximum cost of Rs. 31000. A maximum of Rs. 1100 was incurred towards other expenditure with a mean cost of Rs. 615. The maximum yield was 400 kg. and the minimum yield was 125 kg. with a mean yield of 277 kg (Table 4.1.3.2).

Table 4.1.3.1. Descriptive statistics for fresh planting in Bathery block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	1.00	6.00	2.50	1.58
No. of Vines	200.00	1600.00	680.00	441.71
Machinary (Rs.)	0.00	3312.50	1210.63	1387.21
Labour (Rs.)	4050.00	34900.00	13282.50	8977.16
Manure (Rs.)	400.00	4000.00	2070.00	1296.19
Other expenses (Rs.)	200.00	19200.00	5710.00	5589.36

Table 4.1.3.2. Descriptive statistics for four to seven years old planting in Bathery block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	0.50	5.00	2.40	1.63
No. of Vines	50.00	2000.00	540.00	575.33
Machinary (Rs.)	0.00	3275	661.25	964.013
Labour (Rs.)	10800.00	23100.00	18950.00	4451.53
Manure (Rs.)	800.00	31000.00	5420.00	9056.22
Other expenses (Rs.)	300.00	1100.00	615.00	257.98
Yield (kg.)	125.00	400.00	277.50	112.08

4.1.3.3. Fourth age group

The fourth age group (8 years and above) was in the full yielding stage. The area of holdings ranged from two to four acres with a mean of 2.5 acres. The number of vines ranged from 200 to 800 with a mean of 435. The mean expense for machinary was Rs. 351 with a maximum cost of Rs. 838. The labour cost ranged from Rs. 9400 to Rs. 24300 with a mean cost of Rs. 15890. The mean manure cost was Rs. 4250 with a maximum cost of Rs. 8000. A maximum of Rs. 1200 was incurred as cost towards other expenditure with a mean of cost of Rs. 670. The yield ranged from 125 kg. to 400 kg. with a mean yield of 238 kg (Table 4.1.3.3).

Table 4.1.3.3. Descriptive statistics for eight years old and above planting in Bathery block

Items	Minimum	Maximum	Mean	Std. Deviation
Area of holdings (acre)	2.00	4.00	2.50	0.71
No. of Vines	200.00	800.00	435.00	226.14
Machinary (Rs.)	0.00	837.50	351.25	253.48
Labour (Rs.)	9400.00	24300.00	15890.00	4790.60
Manure (Rs.)	2000.00	8000.00	4250.00	2283.39
Other expenses (Rs.)	350.00	1200.00	670.00	268.95
Yield (kg.)	125.00	400.00	237.50	99.48

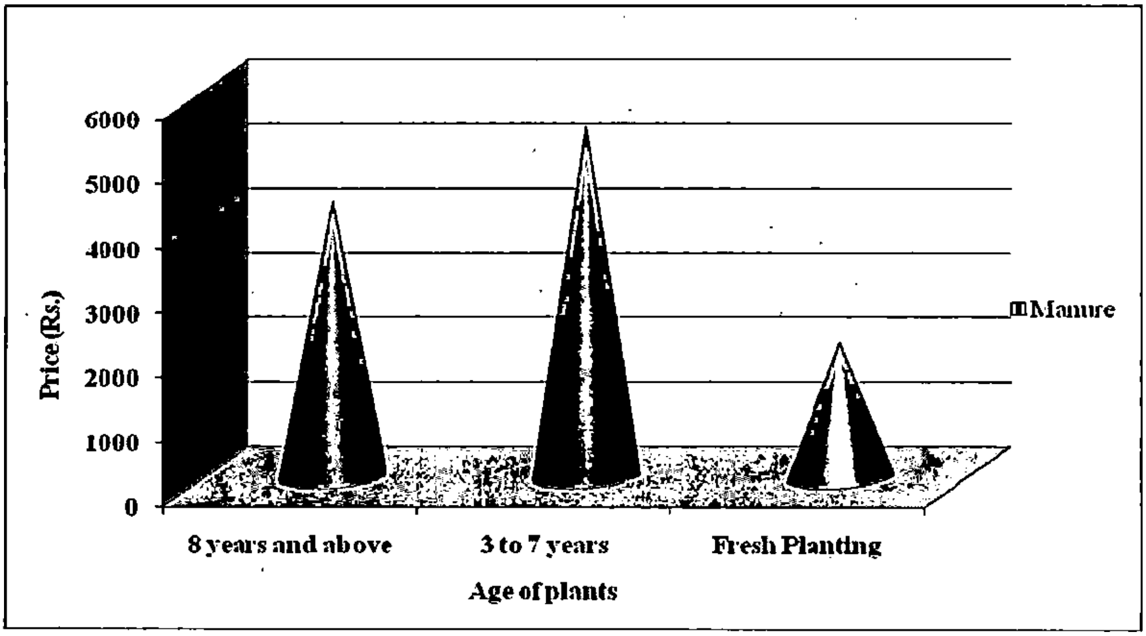


Figure 2.5 Expenditure incurred for manure (Rs.) at different ages of pepper plantation in Bathery block

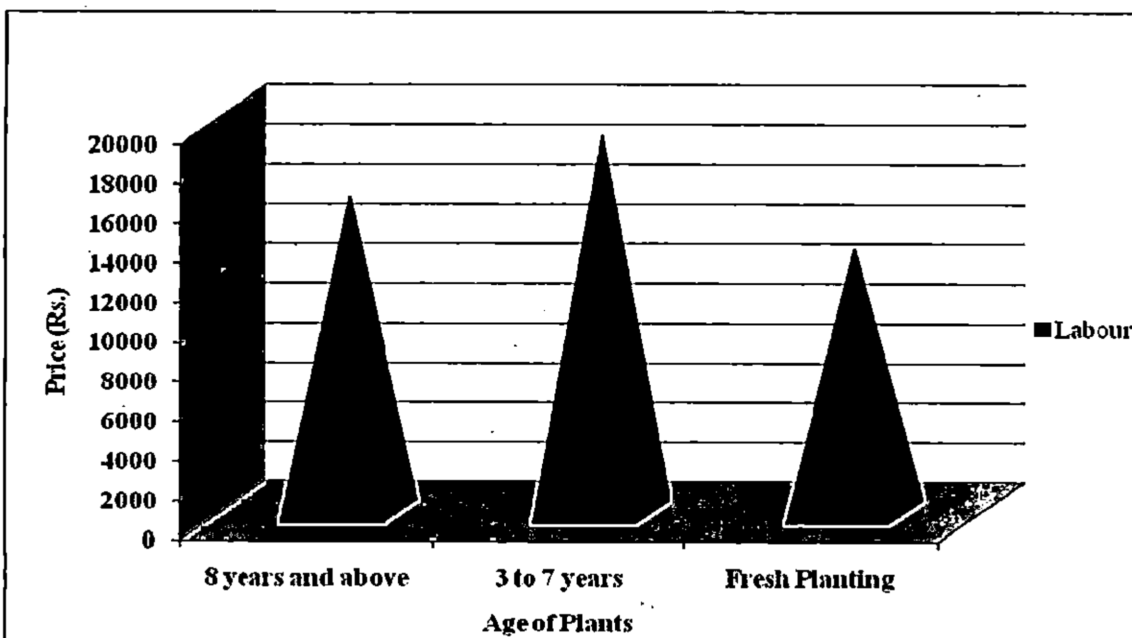


Figure 2.6 Expenditure incurred for labour (Rs.) at different ages of pepper plantation in Bathery block

4.2. Comparison of the costs of various inputs for the different age groups

The costs incurred under the various overheads for the different age groups in each block were summarized on a per vine basis and compared using one way analysis of variance. The results are discussed as follows

4.2.1. Mananthavady block

The expenditures incurred under various heads were found to be maximum for age group four and were significantly higher. It was observed that an amount of Rs. 7.61 for machinary, Rs. 168 for labour, Rs. 23 for manure and Rs. 15 for other expenses were incurred.

4.2.2. Kalpetta block

The expenditures incurred under various heads were found to be maximum for age group four and were significantly higher. It was observed that an amount of Rs. 1.65 for machinary, Rs. 51 for labour, Rs. 15 for manure and Rs. 1 for other expenses were incurred.

4.2.3. Bathery block

The expenditures incurred under various heads were found to be maximum for age group four and were significantly higher. It was observed that an amount of Rs. 0.86 for machinary, Rs. 42 for labour, Rs. 10 for manure and Rs. 2 for other expenses were incurred.

From the summary statistics it was found that irrespective of the blocks, the expenditure on labour charges was the highest followed by manure charges and it was increasing according to the increase in age of the plants.

Table 4.2.1. Expenditure incurred under various heads in Mananthavady block on per vine basis

Items	AG.1	AG.2	AG.3	AG.4
Machinary	1.05[a]	2.67[a]	2.34[a]	7.61[b]
Labour	43.16[a]	51.58[a]	105.47[b]	167.05[c]
Manure	5.05[a]	15.21[ab]	16.11[ab]	23.24[b]
Other expenses	9.30[ab]	4.15[a]	13.55[b]	15.26[b]

Numerals with even superscripts in a row form a homogenous group

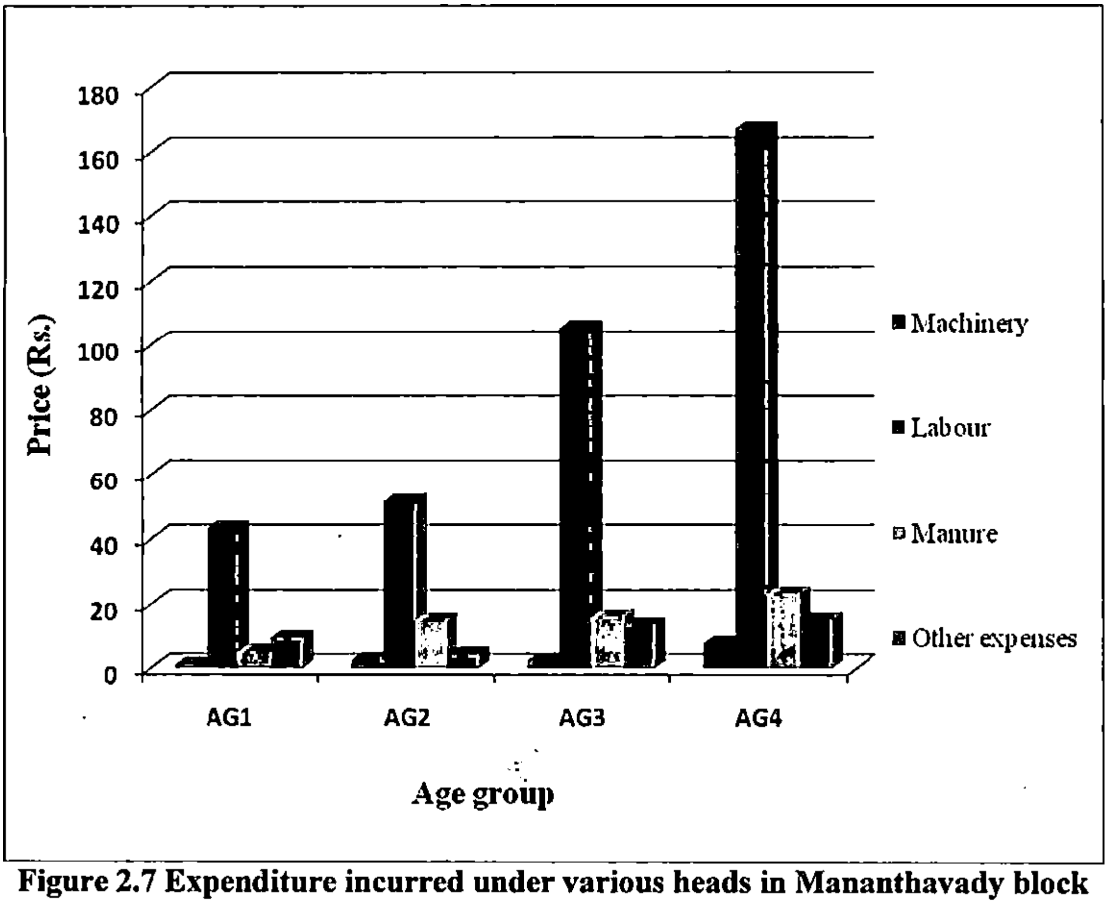


Figure 2.7 Expenditure incurred under various heads in Mananthavady block on a per vine basis

Table 4.2.2. Expenditure incurred under various heads in Kalpetta block on a per vine basis

Items	AG.1	AG.2	AG.3	AG.4
Machinary	1.94[a]	0.60[a]	1.97[a]	1.65[a]
Labour	14.81[a]	28.94[b]	49.89[c]	51.26[c]
Manure	2.76[a]	6.49[b]	12.82[c]	14.69[c]
Other expenses	5.75[b]	0.89[a]	1.60[a]	0.95[a]

Numerals with even superscripts in a row form a homogenous group

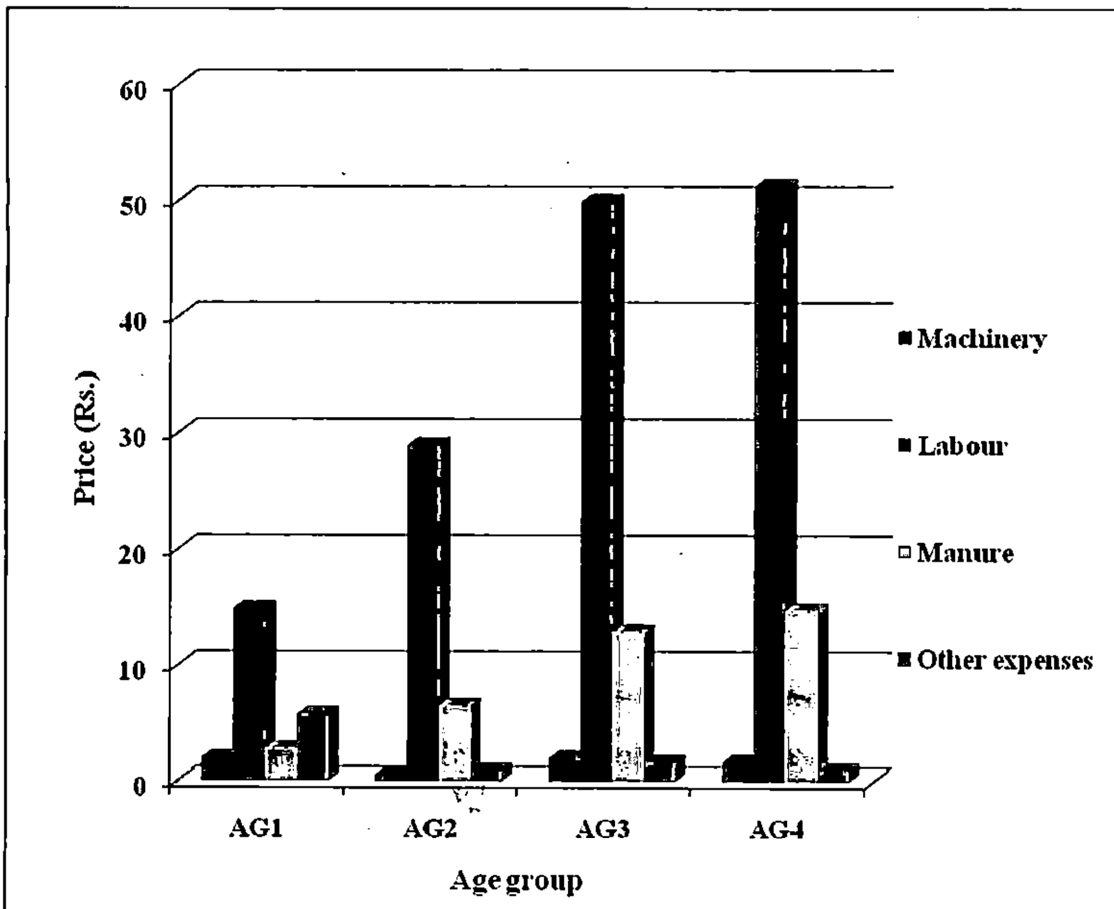


Figure 2.8 Expenditure incurred under various heads in Kalpetta block on a per vine basis

Table 4.2.3. Expenditure incurred under various heads in Bathery block on a per vine basis

Items	AG.1	AG.3	AG.4
Machinary	1.66[a]	2.25[a]	0.86[a]
Labour	18.96[a]	75.33[b]	42.20[ab]
Manure	2.90[a]	14.19[b]	10.33[ab]
Other expenses	7.01[b]	2.40[a]	1.76[a]

Numerals with even super scripts in a row form a homogenous group

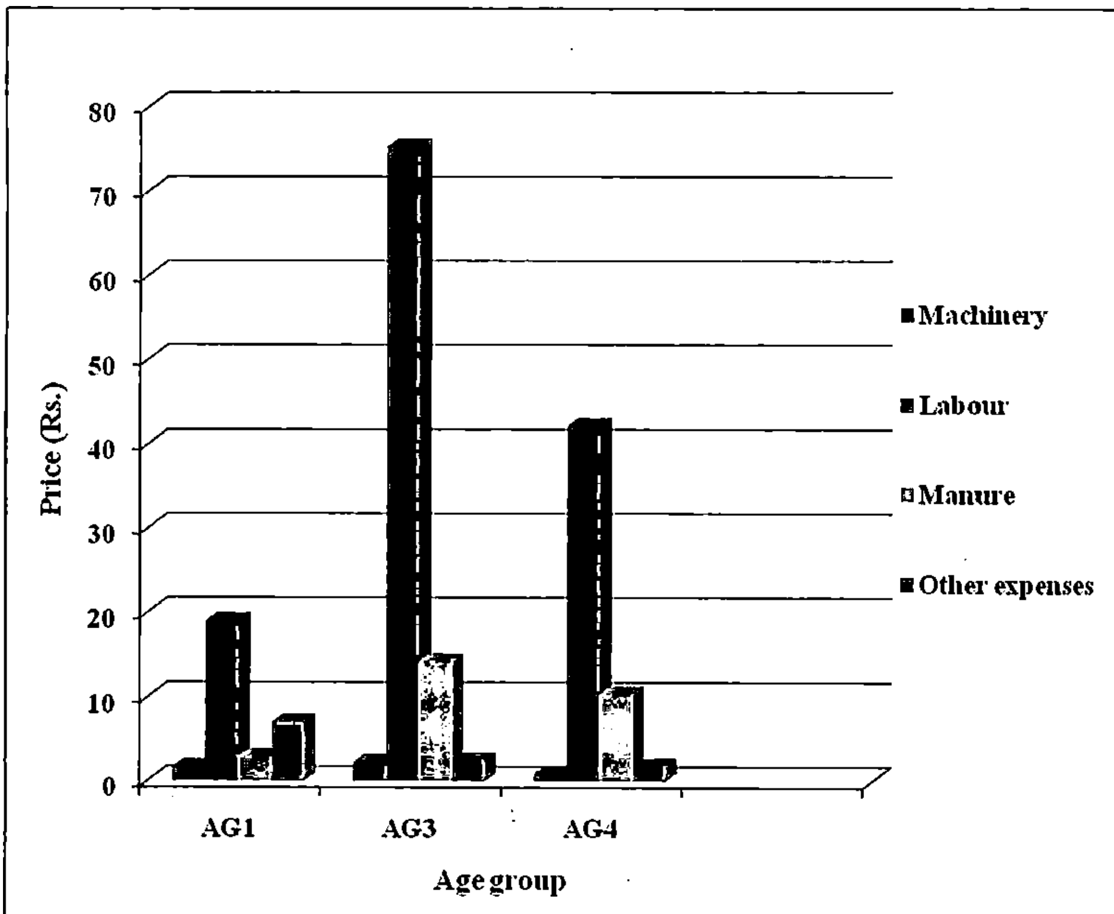


Figure 2.9 Expenditure incurred under various heads in Bathery block on a per vine basis

4.3. Formation and estimation of stochastic frontier

From the summary statistics listed above, it is evident that a wide range of variation existed in the costs towards machinary, labour, manure and other expenses for all the pepper plantations in different age groups in all the three blocks surveyed. Being a rapid estimation survey all the costs were evaluated based on the prevailing conditions. A pepper plantation, which is eight years old and above, might have incurred a lesser cost at the time of planting. Similar would be the case with the other two age groups namely; two to three years old and four to seven years old. Similarly, lesser cost only would have been incurred for subsequent establishment of a plantation at the different stages of growth. Therefore, a rationale is necessary for assessing the present allocation of the costs towards establishment of maximum production efficiency. The stochastic frontier approach is well suited for this purpose with the rationalized cost. To assess the differences in the estimate of production efficiency computed based on the cost at present situation and to compare the same with the production efficiency computed with PV, Stochastic Frontier Analysis been done,

1. separately for each age group in the different blocks using present costs
2. for each age group by pooling over the blocks using present value
3. for each block with age groups three and age group four combined using present value
4. for all the three blocks, compounding all the costs starting from the nursery stage (First age group). up to the steadily bearing stage (Fourth age group) using present value

4.3.1. SFA for each age group in the different blocks using PC

4.3.1.1. Mananthavady

a. Third age group using PC

The mean technical efficiency was found to be 0.79. Plantation M-AG.3-02, M-AG.3-10 and M-AG.3-09 had technical efficiencies 0.99 each. Least technical efficiency was observed for the plantation M-AG.3-03 (0.30) (Table 4.3.1.1.a).

b. Fourth age group using PC

The mean technical efficiency was found to be 0.92. In this age group, almost all the plantations performed equally well. The highest performance was seen in plantation M-AG.4-09 (0.94) followed by the plantation M-AG.4-03 (0.90) (Table 4.3.1.1.b).

4.3.1.2. Kalpetta

a. Third age group using PC

In this age group, the highest technical efficiency was 0.99 and the lowest technical efficiency was 0.12. The mean technical efficiency was 0.73. The plantations K-AG.3-01 and K-AG.3-03 showed poor performance and plantations K-AG.3-02, K-AG.3-07 and the K-AG.3-09 showed high performance in terms of technical efficiency (Table 4.3.1.2.a).

b. Fourth age group using PC

The mean technical efficiency of this age group was 0.84. The plantation K-AG.4-04 showed the highest performance with technical efficiency estimates 0.97 and the Plantation K-AG.4-06 with technical efficiency estimates 0.1 showed lowest performance (Table 4.3.1.2.b).

Table 4.3.1.1.a. Technical efficiency of plantations in the third age group in the Mananthavady block using present costs

Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
M-AG.3-01	0.69	M-AG.3-06	0.86
M-AG.3-02	0.99	M-AG.3-07	0.94
M-AG.3-03	0.30	M-AG.3-08	0.59
M-AG.3-04	0.77	M-AG.3-09	0.99
M-AG.3-05	0.72	M-AG.3-10	0.99
Mean efficiency		**0.79**	

Table 4.3.1.1.b. Technical efficiency of plantations in the fourth age group in the Mananthavady block using present costs

Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
M-AG.4-01	0.91	M-AG.4-06	0.92
M-AG.4-02	0.91	M-AG.4-07	0.93
M-AG.4-03	0.90	M-AG.4-08	0.91
M-AG.4-04	0.93	M-AG.4-09	0.94
M-AG.4-05	0.90	M-AG.4-10	0.91
Mean efficiency		**0.92**	

Table 4.3.1.2.a. Technical efficiency of plantations in the third age group in the Kalpetta block using present costs

Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
K-AG.3-01	0.12	K-AG.3-06	0.65
K-AG.3-02	0.99	K-AG.3-07	0.99
K-AG.3-03	0.41	K-AG.3-08	0.95
K-AG.3-04	0.68	K-AG.3-09	0.99
K-AG.3-05	0.79	K-AG.3-10	0.74
Mean efficiency		**0.73**	

Table 4.3.1.2.b. Technical efficiency of plantations in the fourth age group in the Kalpetta block using present costs

Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
K-AG.4-01	0.95	K-AG.4-06	0.10
K-AG.4-02	0.91	K-AG.4-07	0.35
K-AG.4-03	0.93	K-AG.4-08	0.79
K-AG.4-04	0.97	K-AG.4-09	0.78
K-AG.4-05	0.79	K-AG.4-10	0.92
Mean efficiency		**0.84**	

4.3.1.3 Bathery

a. Third age group using PC

The mean technical efficiency was 0.58. It means that all the plantations of this age group performed poorly in general. However, the plantations B-AG.3-03 and B-AG.3-09 had technical efficiencies 0.97 and 0.99 respectively. Lowest technical efficiency was shown by the plantation B-AG.3-08 (0.01) (Table 4.3.1.3.a).

b. Fourth age group using PC

This age group showed good performance and every plantation performed well. The mean technical efficiency was 0.94. The highest performance was shown by plantation B-AG.4-03 and its technical efficiency was 0.98. The lowest technical efficiency was 0.88 for the plantation B-AG.4-05 (Table 4.3.1.3.b).

Table 4.3.1.3.a. Technical efficiency of plantations in the third age group in the Bathery block using present costs

Estimates of Technical Efficiency			
Plantation	eff.-est.	Plantation	eff.-est.
B-AG.3-01	0.17	B-AG.3-06	0.79
B-AG.3-02	0.79	B-AG.3-07	0.84
B-AG.3-03	0.97	B-AG.3-08	0.01
B-AG.3-04	0.15	B-AG.3-09	0.99
B-AG.3-05	0.55	B-AG.3-10	0.54
Mean efficiency		0.58	

Table 4.3.1.3.b. Technical efficiency of plantations in the fourth age group in the Bathery block using present costs

Estimates of Technical Efficiency			
Plantation	eff.-est.	Plantation	eff.-est.
B-AG.4-01	0.94	B-AG.4-06	0.91
B-AG.4-02	0.97	B-AG.4-07	0.92
B-AG.4-03	0.98	B-AG.4-08	0.96
B-AG.4-04	0.95	B-AG.4-09	0.92
B-AG.4-05	0.88	B-AG.4-10	0.94
Mean efficiency		0.94	

4.3.2. SFA for each age group by pooling over the blocks using PV

a. Third age group with PV

The plantations M-AG.3-09 and M-AG.3-10 showed high technical efficiencies of 0.99 each. The plantations K-AG.3-07 have the lowest technical efficiencies 0.86. The mean technical efficiency was 0.95 (Table 4.3.2.1.a).

b. Fourth age group with PV

The mean technical efficiency was 0.92. The plantation B-AG.4-03 showed highest technical efficiency equal to 0.97. The plantation B-AG.4-04 has the lowest technical efficiency of 0.75 (Table 4.3.2.1.b).

Table 4.3.2.a. Technical efficiency of plantations in the third age group by pooling over the blocks using present value

Estimates of Technical Efficiency					
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**	**Plantation**	**eff.-est.**
M-AG.3-01	0.90	**K-AG.3-01**	0.94	**B-AG.3-01**	0.93
M-AG.3-02	0.95	**K-AG.3-02**	0.94	**B-AG.3-02**	0.87
M-AG.3-03	0.95	**K-AG.3-03**	0.91	**B-AG.3-03**	0.95
M-AG.3-04	0.96	**K-AG.3-04**	0.91	**B-AG.3-04**	0.96
M-AG.3-05	0.97	**K-AG.3-05**	0.93	**B-AG.3-05**	0.94
M-AG.3-06	0.97	**K-AG.3-06**	0.94	**B-AG.3-06**	0.98
M-AG.3-07	0.98	**K-AG.3-07**	0.86	**B-AG.3-07**	0.94
M-AG.3-08	0.98	**K-AG.3-08**	0.95	**B-AG.3-08**	0.93
M-AG.3-09	0.99	**K-AG.3-09**	0.95	**B-AG.3-09**	0.98
M-AG.3-10	0.99	**K-AG.3-10**	0.97	**B-AG.3-10**	0.97
Mean efficiency			**0.95**		

Table 4.3.2.b. Technical efficiency of plantations in the fourth age group by pooling over the blocks using present value

Estimates of Technical Efficiency					
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**	**Plantation**	**eff.-est.**
M-AG.4-01	0.95	**K-AG.4-01**	0.96	**B-AG.4-01**	0.89
M-AG.4-02	0.92	**K-AG.4-02**	0.96	**B-AG.4-02**	0.96
M-AG.4-03	0.90	**K-AG.4-03**	0.95	**B-AG.4-03**	0.97
M-AG.4-04	0.95	**K-AG.4-04**	0.96	**B-AG.4-04**	0.75
M-AG.4-05	0.95	**K-AG.4-05**	0.92	**B-AG.4-05**	0.85
M-AG.4-06	0.86	**K-AG.4-06**	0.90	**B-AG.4-06**	0.95
M-AG.4-07	0.93	**K-AG.4-07**	0.95	**B-AG.4-07**	0.92
M-AG.4-08	0.95	**K-AG.4-08**	0.87	**B-AG.4-08**	0.93
M-AG.4-09	0.96	**K-AG.4-09**	0.88	**B-AG.4-09**	0.94
M-AG.4-10	0.96	**K-AG.4-10**	0.94	**B-AG.4-10**	0.94
Mean efficiency			**0.92**		

4.3.3. SFA for each block with age groups three and age group four combined using PV

a. Mananthavady

The mean technical efficiency was 0.95. All the plantations in this block had an above average performance (Table 4.3.3.a).

b. Kalpetta

The mean technical efficiency was 0.81. The highest technical efficiency of 0.96 was observed for plantation K-AG.4-01 and K-AG.3-07. The lowest technical efficiency was for the plantation K-AG.3-01(0.34) (Table 4.3.3.b).

c. Bathery

The mean technical efficiency was 0.92. The lowest technical efficiency was 0.5496 and was seen in plantation B-AG.4-06. The highest technical efficiency was observed in the plantations B-AG.3-01, B-AG.3-02 and B-AG.4-05 (1.00) (Table 4.3.3.c).

Table 4.3.3.a. Technical efficiency of plantations in the third and fourth age group combined using present value in Mananthavady block

Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
M-AG.3-01	0.94	M-AG.4-01	0.93
M-AG.3-02	0.95	M-AG.4-02	0.93
M-AG.3-03	0.94	M-AG.4-03	0.93
M-AG.3-04	0.96	M-AG.4-04	0.94
M-AG.3-05	0.95	M-AG.4-05	0.94
M-AG.3-06	0.94	M-AG.4-06	0.93
M-AG.3-07	0.97	M-AG.4-07	0.95
M-AG.3-08	0.97	M-AG.4-08	0.94
M-AG.3-09	0.98	M-AG.4-09	0.96
M-AG.3-10	0.98	M-AG.4-10	0.95
Mean efficiency		0.95	

Table 4.3.3.b. Technical efficiency of plantations in the third and fourth age group combined using present value in Kalpetta block

Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
K-AG.3-01	0.34	K-AG.4-01	0.96
K-AG.3-02	0.80	K-AG.4-02	0.94
K-AG.3-03	0.90	K-AG.4-03	0.94
K-AG.3-04	0.85	K-AG.4-04	0.96
K-AG.3-05	0.29	K-AG.4-05	0.90
K-AG.3-06	0.95	K-AG.4-06	0.27
K-AG.3-07	0.96	K-AG.4-07	0.75
K-AG.3-08	0.92	K-AG.4-08	0.87
K-AG.3-09	0.95	K-AG.4-09	0.83
K-AG.3-10	0.91	K-AG.4-10	0.92
Mean efficiency		**0.81**	

Table 4.3.3.c. Technical efficiency of plantations in the third and fourth age group combined using present value in Bathery block

Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
B-AG.3-01	1.00	B-AG.4-01	0.91
B-AG.3-02	1.00	B-AG.4-02	0.93
B-AG.3-03	0.88	B-AG.4-03	0.97
B-AG.3-04	0.94	B-AG.4-04	0.96
B-AG.3-05	0.94	B-AG.4-05	1.00
B-AG.3-06	0.95	B-AG.4-06	0.55
B-AG.3-07	0.88	B-AG.4-07	0.94
B-AG.3-08	0.94	B-AG.4-08	0.93
B-AG.3-09	0.98	B-AG.4-09	0.92
B-AG.3-10	0.94	B-AG.4-10	0.90
Mean efficiency		**0.92**	

4.3.4. SFA for all the three blocks compounding all the costs starting from the nursery stage (First age group) up to the steadily bearing stage (Fourth age group) using present valve

a. Mananthavady (PV)

The mean technical efficiency was 0.93. The lowest technical efficiency was 0.87 for the plantations M-AG.4-02 and M-AG.4-05. The highest technical efficiency was for the plantation M-AG.4-04 (0.97) (Table 4.3.4.a).

b. Kalpetta

The mean technical efficiency was 0.91. The lowest technical efficiency 0.78 and was seen in the plantation K-AG.4-07. The highest technical efficiency was seen in the plantation K-AG.4-06 and K-AG.4-10 (1.00) (Table 4.3.4.b).

c. Bathery

The mean technical efficiency was 0.94. The lowest technical efficiency 0.87 was seen in the plantation B-AG.4-05. The highest technical efficiency was seen in the plantation B-AG.4-03 (0.98) (Table 4.3.4.c).

Table 4.3.4.a. Technical efficiency estimated compounding all the costs starting from the nursery stage to the steady bearing stage in Mananthavady block

Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
M-AG.4-01	0.94	M-AG.4-06	0.93
M-AG.4-02	0.87	M-AG.4-07	0.94
M-AG.4-03	0.91	M-AG.4-08	0.94
M-AG.4-04	0.97	M-AG.4-09	0.95
M-AG.4-05	0.87	M-AG.4-10	0.94
Mean efficiency		**0.93**	

Table 4.3.4.b. Technical efficiency estimated compounding all the costs starting from the nursery stage to the steady bearing stage in Kalpetta block

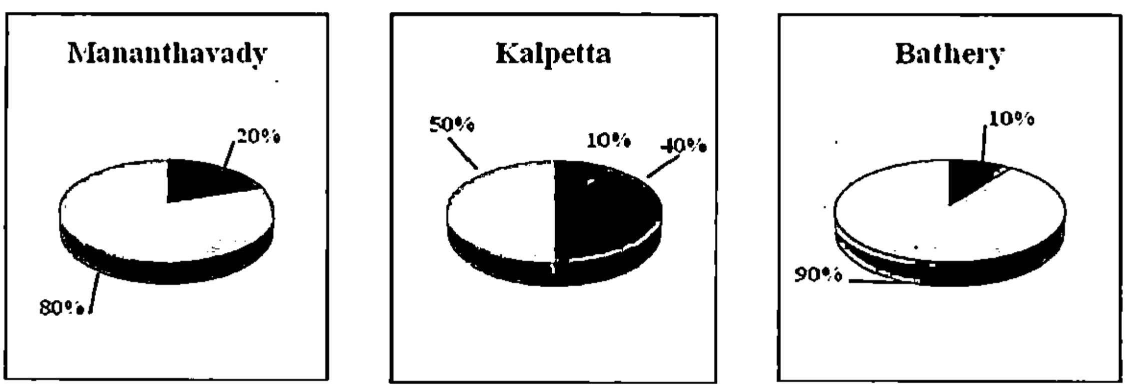
Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
K-AG.4-01	0.98	K-AG.4-06	1.00
K-AG.4-02	0.89	K-AG.4-07	0.78
K-AG.4-03	0.84	K-AG.4-08	0.89
K-AG.4-04	0.97	K-AG.4-09	0.80
K-AG.4-05	0.92	K-AG.4-10	1.00
Mean efficiency		**0.91**	

Table 4.3.4.c. Technical efficiency estimated compounding all the costs starting from the nursery stage to the steady bearing stage in Bathery block

Estimates of Technical Efficiency			
Plantation	**eff.-est.**	**Plantation**	**eff.-est.**
B-AG.4-01	0.94	**B-AG.4-06**	0.91
B-AG.4-02	0.97	**B-AG.4-07**	0.92
B-AG.4-03	0.98	**B-AG.4-08**	0.96
B-AG.4-04	0.96	**B-AG.4-09**	0.92
B-AG.4-05	0.87	**B-AG.4-10**	0.94
Mean efficiency		**0.94**	

4.4. Farm specific technical efficiency in different blocks

The technical efficiency of all the plantations considered for the study have a value equal to or greater than 80 percentage. In Mananthavady 80 percentage of the farms were having a technical efficiency greater than or equal to 0.9. In Bathery also 90 percentage of the farms showed technical efficiency greater than 0.9, Where as in Kalpetta only 50 percentage of the farms were found to be technical efficient in the range 0.9 to 1. The attainment of technical efficiency of 80 per cent indicates that efficiency of the farmers could be increased by about 20 per cent to attain maximum possible output. The results also suggests that farmers could increase output through more intensive use of labour, vine and fertilizer inputs given the prevailing state of technology.



(0.7 – 0.8) (0.8 – 0.9) (0.9 – 1.0)

Figure 2.10. Farm specific technical efficiency in different blocks

4.5 Comparison of technical efficiency estimated using present costs and present value

Improved estimates of technical efficiencies were obtained for the plantations in the fourth age group of Mananthavady and Kalpetta. As regards Bathery not much of differences were noticed. Estimation of TE using PV is advantageous when technical efficiencies are computed by combining the third age group, which is in its early stage of bearing, and the fourth age group, which is in its full bearing stage. It is quite advantageous to have realistic estimate of the costs right from the establishment of the nursery. It will be extremely worthwhile to analyze the factors that influence the TE. For this purpose, the regression of TE on the factors like area of holdings, number of vines, expenses for machinary, labour, manure and other expenses was obtained.

4.6. Factors affecting technical efficiency

Factors affecting the technical efficiency were identified by fitting regression of TE on the variables viz; area of holdings, number of vines, expense for machinary, labour, manure and other expenses. The fit was good for the data from Mananthavady and Kalpetta blocks.

The regression equation for Mananthavady could explain 97 per cent variation in technical efficiency. The inputs like area of holdings, number of vines, expenses for labour, manure and other expenses were found to be significantly contributing to TE. The area of holdings, number of vines, and other expenses negatively influenced TE, where as expenses for labour and manure positively influenced TE.

The regression equation for Kalpetta could explain 97 per cent variation in technical efficiency. The inputs like area of holdings, expenses for machinary, labour, and other expenses were found to be significantly contributing to TE. The expenses for machinary, manure and other expenses positively influenced TE, where as area of holdings negatively influenced TE.

The regression equation for Bathery could explain 76 per cent variation in technical efficiency.

In general when the area of holdings increased the technical efficiency seemed to decrease. This is in agreement with the findings of Ali *et. al.* (1996) who observed that the size of holding and fragmentation of land of farmers contributed positively to inefficiency. The non-optimum use was explained by holding size, education, credit, and subsistence needs. Small farms seemed to be more efficient than large farms in the region.

Table 4.6.1. Factors affecting technical efficiency

	Mananthavady			Kaltpetta			Bathery		
	B	t	Sig.	B	t	Sig.	B	t	Sig.
(Constant)	0.851	57.4446	0.0000	1.3198	18.86	0.0003	0.8242	12.0696	0.0012
Area of holdings (x_1)	-0.0015	-3.2468	0.0476	-0.2276	-5.3631	0.0127	0.0118	0.4904	0.6575
No. of Vines (x_2)	-0.0013	-2.9934	0.0580	-0.0019	-2.4369	0.0928	-0.0002	-0.3708	0.7354
Machinary (x_3)	0.0001	2.2129	0.1138	0.0002	6.3007	0.0081	0.0001	0.9238	0.4237
Labour (x_4)	0.0001	4.3635	0.0223	0.0001	-5.6945	0.0107	0.0001	0.9323	0.4200
Manure (x_5)	0.0001	2.183	0.117	0.0002	6.8456	0.0064	0.0001	-0.8491	0.4582
Other expenses (x_6)	-0.0001	-5.3272	0.0129	0.0004	4.2322	0.0241	0.0001	-0.2857	0.7937
R Square	0.97			0.96			0.76		

With proper labour management the technical efficiency can be significantly increased. This is in agreement with the findings of Ahmed *et. al.* (2005) who pointed that credit, capital, hired labor, fertilizer and irrigation had significant positive effects in sorghum production levels, while sorghum area showed a negative and significant effect. Size of holding, education level, tenants' experience, household size, contact with extension agents and farm location were significant in explaining tenants' technical inefficiency. Alemu *et. al.* (2009) observed that maximum likelihood estimates indicated positive and significant elasticities for inputs such as land, labour and fertilizer. Besides, education, proximity to markets, and access to credit were found to reduce inefficiency levels significantly. The predicted coefficient of household size was negative and is significant at 5 per cent.

Table 4.6.2. Regression of technical efficiency on input variables in different blocks

Sl. No.	Regression equation	R^2 (%)
1	$TE_{(M)} = 0.8510 - \underset{(0.0005)}{0.0015^{*}} x_1 - \underset{(0.0004)}{0.0013^{*}} x_2 + \underset{(0.0001)}{0.0001} x_3 + \underset{(0.0001)}{0.0001^{*}} x_4 + \underset{(0.0001)}{0.0001^{**}} x_5 - \underset{(0.0001)}{0.0001^{*}} x_6$	97
2	$TE_{(K)} = 1.3198 - \underset{(0.0424)}{0.2276^{*}} x_1 - \underset{(0.0008)}{0.0019^{*}} x_2 + \underset{(0.000)}{0.0002^{**}} x_3 + \underset{(0.000)}{0.0001^{*}} x_4 + \underset{(0.000)}{0.0002} x_5 + \underset{(0.000)}{0.0004^{*}} x_6$	97
3	$TE_{(B)} = 0.8242 + \underset{(0.0240)}{0.0118} x_1 - \underset{(0.0005)}{0.0002} x_2 + \underset{(0.000)}{0.0001} x_3 + \underset{(0.000)}{0.0001} x_4 + \underset{(0.000)}{0.0001} x_5 + \underset{(0.000)}{0.0001} x_6$	76

** Significant at 5% level and ** significant at 1% level*

$TE_{(M)}$ - Regression equation for Mananthavady

$TE_{(K)}$ - Regression equation for Kalpetta

$TE_{(B)}$ - Regression equation for Bathery

Managing all the requirements of the crop over a large holding area might be difficult especially for want of sufficient labour force. This is further reinforced by the fact that more labour intensive, more profitable is the crop. Retention of senile and productive vines might be another factor negatively influencing TE. Agbonlahor (2010) recommended that technical and management training/workshop should be organized by relevant government agencies to regularly update operators' knowledge. Import policies should be targeted to encourage acquisition and use of modern sawmilling machines and equipment. Also, public power supply to the sawmill clusters should be improved to reduce the high processing cost associated with the use of diesel powered electricity generation sets. We can also recommend those kind of extension programme in pepper cultivars. Wakili (2012) observed that the inefficiency variable was specified as those relating to farmer's socioeconomic characteristics. They include the farmer's level of educational attainment, membership of association, contact with extension agents, household size and gender.

Miniraj and Nybe (2011) reported that predominance of poor genetic stock, incidence of disease and pests and non-adaption of scientific cultivation practices are the major factors affecting pepper cultivation. In Wayanad 77 per cent of farmers applied organic manures alone while 22 per cent applied organics along with inorganics. Totally there were 30 farms which were certified organic, most of which situated in Sulthan Bathery panchayath. It may be noted that there are several NGO's in wayanad who promote organic farming in pepper under various certification procedures.

Among diseases, foot rot incidence was high (91%) in all the panchayats. Slow wilt and other disease including little leaf damaged six percent vines whereas three percent of vines were reported to be free from any disease. With respect to infestation of pests on pepper vine, 99 percent farms were free of any pests. Incidence of thrips and other minor pests were insignificant. It may be noted that in Wayanad more than the vine, it was the standard, which was affected by pests. It is to be emphasized that erythrina trees in Wayanad have been drastically infested by the wasp and have almost totally wiped out from certain pockets.

SUMMARY

5. SUMMARY

Usually stochastic frontier models are fitted to data of crops, which are having duration of less than one year. This is because; the cost of cultivation is readily available. If there were records of the exact cost of cultivation as in the case with vegetable crops, there might be no problem in fitting of stochastic frontier models to any phenomena involving an output and a vector of inputs. This is usually possible in industries as many literature are available on stochastic frontier models related to industries.

As regards the scenario of agriculture where output is of prime importance for a set of inputs, stochastic frontier model will be description of a notion that has to set right the present system and bring an output, which is much attractive.

Very few farmers keep record of the expenditure incurred on the various inputs, and very rarely the output realized. A surveyor usually finds difficulty to elucidate the information on the exact cost of inputs and the realistic output as he is at the mercy of the respondent for information.

Stochastic frontier approaches never been tried in plantation crops sector where, the plantations takes a stipulated time to give a fruitful output right from the stage of establishment. As total cost from the establishment stage itself is necessary to have a stochastic frontier model fitted to plantation crops, realistic cost estimation for the different stages of establishment is necessary.

A farmer's hypothetical figure for the cost involved at the various stages of establishment of crop is of no use to arrive at a summary figure. For this purpose, a rapid estimation survey was conducted in Mananthavady, Kalpetta and Bathery blocks. Being a rapid estimation survey all the costs were evaluated based on the prevailing conditions. A pepper plantation, which is eight years old and above, might have incurred a lesser cost at the time of planting. Similar would be the case with the other two age groups namely; two to three years old and four to seven years old. Similarly, lesser cost only would have been incurred for subsequent establishment of a plantation at the different stages of growth. Therefore, a rationale is necessary for assessing the present allocation of the costs towards establishment of maximum production efficiency. The stochastic frontier approach is well suited for this purpose with the rationalized cost. To assess the differences in the estimate of production efficiency computed based on the cost at present situation and to compare the same with the production efficiency computed with Present Value (PV), Stochastic Frontier Analysis (SFA) has been done separately using both the costs.

The mean area of holdings under first age group was 7.61 acres with a mean number of 325 vines in the Mananthavady block. The corresponding mean figures as regards, to as machinary, labour, manure and other expenses were Rs. 399, Rs. 15383, Rs. 1730 and Rs. 3340 respectively. As regards the second age group, the mean figures were 9.22 acre, 282 nos., Rs. 812, Rs. 15583, Rs. 4695 and Rs. 1215 for area of holdings, number of vines, machinary, labour, manure and other expenses respectively. With respect to third age group, the mean figures were 5.17 acre, 362 nos., Rs. 911, Rs. 41045, Rs. 6070, Rs. 5610 and 1035 kg. for area of holdings, number of vines, machinary, labour, manure, other expenses and yield respectively. In the fourth age group, the mean figures were 8.64 acre, 90 nos., Rs. 592, Rs. 14068, Rs. 1905, Rs. 1250 and 374.5 kg. for area of holdings, number of vines, machinary, labour, manure, other expenses and yield respectively.

In Kalpetta block, the mean area of holdings under first age group was 1.69 acres with a mean number of 401 vines. The corresponding mean figures as regards to machinary, labour, manure and other expenses were Rs. 789, Rs. 6260, Rs. 1302 and Rs. 2680 respectively. As regards the second age group, the mean figures were 0.94 acre, 295 nos., Rs. 168, Rs. 8890, Rs. 1990 and Rs. 265 for area of holdings, number of vines, machinary, labour, manure and other expenses respectively. In the third age group, the mean figures were 1.34 acre, 240 nos., Rs. 446, Rs. 11760, Rs.

3135, Rs. 365 and 193 kg. for area of holdings, number of vines, machinary, labour, manure, other expenses and yield respectively. With respect to fourth age group, the mean figures were 1.43 acre, 300 nos., Rs. 576, Rs. 15115, Rs. 4370, Rs. 290 and 260 kg. for area of holdings, number of vines, machinary, labour, manure, other expenses and yield respectively.

In Bathery block, data for the second age group was not available. The mean area of holdings under first age group was 2.50 acres with a mean number of 680 vines. The corresponding mean figures as regards, to machinary, labour, manure and other expenses were Rs. 1211, Rs. 13283, Rs. 2070 and Rs. 5710 respectively. As regards the third age group, the mean figures were 2.40 acre, 540 nos., Rs. 661, Rs. 18950, Rs. 5420, Rs. 615 and 277.5 kg. for area of holdings, number of vines, machinary, labour, manure, other expenses and yield respectively. With respect to fourth age group, the mean figures were 2.50 acre, 435 nos., Rs. 351, Rs. 15890, Rs. 4250, Rs. 670 and 238 kg. for area of holdings, number of vines, machinary, labour, manure, other expenses and yield respectively.

Irrespective of the blocks, the expenditure on labour charges was the highest followed by manure charges and it was increasing according to the increase in age of plants. A wide range of variation existed towards area of holdings, number of vines, machinary, labour, manure and other expenses for all the pepper plantations in the different age groups in the entire three blocks surveyed. The stochastic frontier analysis was done using the PV as also with the PC. The SFA was done, separately for each age group in the different blocks using PV, for each age group by pooling over the blocks using PV, for each block with age groups three and age group four combined using PV, and for all the three blocks compounding all the costs starting from the nursery stage (First age group) up to the steadily bearing stage(Fourth age group) using PV.

The SFA for each age group in the different blocks using present costs revealed a mean technical efficiency 0.79 for the plantations in the third age group and a mean technical efficiency of 0.92 for the plantations in fourth age group of Mananthavady block. The corresponding mean technical efficiency for the plantations in third and fourth age group of Kalpetta and Bathery blocks were 0.73, 0.84; 0.58, 0.94 respectively.

The stochastic frontier approach for each age group by pooling over the blocks, worked out using PV revealed a mean technical efficiency of 0.95 and 0.92 for the plantations in third and fourth age group respectively.

The SFA for each blocks with age groups three and four combined using PV resulted in a mean technical efficiency of 0.95 for Mananthavady, 0.78for Kalpetta and 0.92 for Bathery blocks.

The SFA for all the three blocks compounding all the costs starting from the nursery stage (First age group) up to the steadily bearing stage(Fourth age group) using PV was worked out. The mean technical efficiency was observed to be 0.93, 0.91 and 0.94 for Mananthavady, Kalpetta and Bathery Blocks respectively.

In all the modes of estimation of technical efficiency using SFA analysis, improved estimates of technical efficiency were obtained. So as to further assess the factors influencing technical efficiency, the regression of TE. on the factors like area of holdings, no. of vines, expenses for machinary, labour, manure and other expenses was obtained.

Factors affecting the technical efficiency were identified by fitting regression of TE. on the variables viz; area of holdings, number of vines, expense for machinary, labour, manure and other expense. Using the above variables 97 per cent of the variation in T.E. could be explained. When the area of holdings increased, the technical efficiency seemed to decrease. With proper labour management, the technical efficiency can be significantly increased. Managing all the requirements of the crop over a large holding area might be difficult especially for want of sufficient labour force. This is further reinforced by the fact that more labour intensive, more profitable is the crop. Retention of senile and productive vines might be another factor negatively influencing TE.

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FORMATION AND EFFICIENT ESTIMATION OF STOCHASTIC FRONTIER PODUCTION FUNCTIONS

By

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ABSTRACT OF THESIS

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ABSTRACT

Technological change and efficiency improvement are important sources of productivity growth in any economy. The concept of technical efficiency (TE) is based on input and output relationships. Technical inefficiency arises when actual or observed output from a given input mix is less than a possible mix. The analysis of technical efficiency involves the assessment of the degree to which the production technologies are utilized.

The present investigation on "Formation and efficient estimation of stochastic frontier production functions" was carried out in the Department of Agricultural Statistics, College of Horticulture, Vellanikkara during 2010-13, to assess the present economics of pepper cultivation, to formulate new stochastic frontier production functions and to compare them. The secondary data collected from the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara on area of holdings, number of vines, yield, expenses for machinary, labour, manure, and other expenses for the cultivation of pepper in the three blocks viz; Mananthavady, Kalpetta and Bathery were used for the analysis.

The summary statistics revealed that irrespective of the blocks, the expenditure on labour was the highest followed by expenditure on manure and it was increasing according to the increase in age of plants.

For the stochastic frontier production model to be realistic, exact measurement of the cost of the inputs as also the realized output is extremely necessary. Very few farmers keep records of the expenditure incurred on the various inputs and very rarely the output realized.

Vegetable crops have a short duration. So the farmer will be in a position to give realistic figures regarding the various inputs as also the outputs. As regards

plantation crops, there will be a lag right from establishment of the crop to the steady bearing stage. Therefore, it will be very difficult to trace back the exact cost, as no records would be available about the costs incurred. A rapid estimation survey is the only feasibility where in simultaneous estimation of the costs involved at from the nursery through the various stages of growth can be observed.

Since a farmer who is already having a steady bearing crop, would have incurred lesser costs through the previous stages of growth of the crop, it is most feasible to use the concept of present worth to arrive at exact costs of previous stages of the crop. The stochastic frontier analysis was done using the present value (PV) as also with the present cost.

The stochastic frontier analysis (SFA) was done for all the three blocks compounding all the costs starting from the nursery stage (First age group) up to the steady bearing stage (Fourth age group) using PV. The mean technical efficiency was observed to be 0.93, 0.91 and 0.94 for Mananthavady, Kalpetta and Bathery Blocks respectively. The stochastic frontier approach for each age group by pooling over the blocks, were also worked out using PV and it revealed a mean technical efficiency of 0.95 and 0.92 for the plantations in the third and fourth age groups respectively.

To assess the factors influencing technical efficiency, the regression of TE on the factors like area of holdings, number of vines, cost for implements and machinary, labour, manure and other expenses was fitted for each block. About 91 per cent of the variation in technical efficiency could be explained using these variables. When the area of holdings increased, the technical efficiency seemed to decrease. With proper labour management, the technical efficiency can be significantly improved.