Analysis of factors affecting the technical efficiency of arabica coffee producers in Cameroon

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AERC Research Paper 163
African Economic Research Consortium, Nairobi
January 2007

THIS RESEARCH STUDY was supported by a grant from the African Economic Research Consortium. The findings, opinions and recommendations are those of the author, however, and do not necessarily reflect the views of the Consortium, its individual members or the AERC Secretariat.

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

Printed by: Modern Lithographic (K) Ltd.
P.O. Box 52810-City Square
Nairobi 00200, Kenya

ISBN 9966-778-06-3

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Abstract

This study analyses 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 are specified to be functions of socioeconomic variables, is 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 show some increasing returns to scale in coffee production. The mean technical efficiency index is estimated at 0.896, and 32% of the farmers surveyed have technical efficiency indexes of less than 0.91. The analysis also reveals that the educational level of the farmer and access to credit are the major socioeconomic variables influencing the farmers' technical efficiency. Finally, the findings prove that further productivity gains linked to the improvement of technical efficiency may still be realized in coffee production in Cameroon.

Keywords: Technical efficiency, stochastic production frontier, arabica coffee, Cameroon

JEL classification: O13, Q18, C21, R30

Acknowledgements

This study has benefited from the useful comments and suggestions and the support from a number of persons and institutions. I appreciate the contributions of all members of AERC's Group AT for their intellectual support and valuable comments. I am grateful as well for the encouragement of colleagues of the Department of Monitoring and Evaluation, Secretariat General, Ministry of Agriculture and Rural Development.

I also thank AERC for the technical and financial support for the study and the AERC secretariat for providing the necessary documentation and information. However, the views expressed in the study are mine, and I am responsible for any errors remaining.

1. Introduction

The agricultural sector is of great importance to Cameroon’s economy. It employs nearly 60% of the active population, ensures a large share of the country’s food security, generates foreign exchange receipts (up to 55% of export receipts) and contributes for up to 20% of gross domestic product (GDP). Moreover, agricultural activity induces most of the spread effects on other sectors of the economy, thus contributing to export diversification, job creation, and poverty reduction (INS, 2005).

The performance of this sector has been disappointing in recent years, however, largely because of a continuous decline in output. The rate of decline in agricultural output was -4.5% on the average between 1988/89 and 1991/92, thus reflecting a serious slump in producer income during the period (Republic of Cameroon, 1996).[1] The economic literature points to the decline in primary commodity prices, the appreciation of the CFA franc (CFAF) relative to the US dollar, and certain domestic distortions such as the high costs of inputs, the cumbersomeness of the administrative machinery and the poor management of public enterprises, as the main causes of the fall in agricultural output.[2]

Faced with the continued deterioration and stagnation of the agricultural sector, and a significant disinvestment in rural areas, the Government of Cameroon took a series of reform measures to attenuate the effects of the crisis and safeguard the country’s agricultural production potential. These measures were in keeping with the general pattern of the first structural adjustment programme (SAP) adopted in September 1988, as well as the government's New Agricultural Policy, whose major goals were to:

- Liberalize trade in traditional agricultural exports such as coffee and cocoa.
- Eliminate input subsidies (fertilizers and pesticides).
- Privatize agricultural development activities, promote the farmer’s accountability for cost recovery and establish new cooperatives.
- Restructure agricultural sector public enterprises and parastatals in order to achieve a better balance in their financial position and broader autonomy in internal management.

The overall objective of these measures was to create a sectoral environment likely to improve farm productivity, reduce production costs to make agricultural products more competitive and increase producer income.

The research problem

Cocoa and coffee are Cameroon's most important export crops. During the period between 1990 and 1992, receipts from cocoa and coffee (arabica and robusta) exports amounted to nearly 27% of government foreign revenue, only to drop to 16% by 1997/98. For the primary sector as a whole, both coffee and cocoa today represent 40% of total exports. Relative to GDP, it is estimated that their share amounts to around 2% of national GDP, 6% of primary GDP and 33% of the GDP fraction derived from the export subsector (Gilbert et al., 1999). Moreover, the evaluation of the comparative advantage of traditional export crops revealed domestic resources cost coefficient (DRC) values of about 0.31, 0.47 and 0.33, respectively, for arabica coffee, robusta coffee and cocoa (Nchare, 1999). The low DRC value of arabica coffee relative to those of robusta coffee and cocoa indicates that Cameroon has a more significant comparative advantage in arabica coffee production. Consequently, arabica coffee is a very profitable crop deserving particular attention in the context of development policies concerning agricultural exports and domestic resources allocation.

In recent years, however, world market prices for coffee of both types have been very low, and Cameroon's production has fallen. Faced with the fall in prices and quantity produced, the Cameroon government, in the context of its poverty alleviation programme in rural areas, decided to increase coffee production to improve farmers' income. To revive arabica coffee production, two solutions are possible, given the saturated nature of land in producing areas. They are: regenerating coffee plants by replacing existing coffee plants with the most improved and productive varieties such as the Java variety, on the one hand, and improving the productive performance of coffee plantations, on the other.

In the context of present economic circumstances, characterized in the aftermath of economic liberalization by public finance imbalances and significant external debt service payments, the second solution seems to be more appropriate since it is easier to implement and appears relatively less expensive for the Cameroon government. However, this solution can only be realized if the sources of inefficiency are identified. Moreover, if the production of this undeniably important crop is to continue, the reduction of unit production costs becomes imperative, given the persistent decline in world coffee prices, which substantially affects profitability and hence producer income.

This objective can only be attained by improving the technical efficiency of producers, that is, their ability to derive the greatest amount of output possible from a fixed quantity of inputs. In fact, the presence of shortfalls in efficiency means that output can be increased without requiring additional conventional inputs or new technologies. If this is the case, then empirical measures of efficiency are necessary in order to determine the magnitude of the gain that could be obtained by improving performance in production with a given technology. Consequently, it is necessary to analyse the technical efficiency of arabica coffee producers and to identify its determinants. To that end, the research problem of this study can be stated in the following manner: how do we improve the productive performance of arabica coffee producers in order to increase their incomes and enable Cameroon to regain its market shares in international markets in a context of land saturation and financial resource scarcity? This study is based on this main question.

Objectives and significance of the study

The main objective of the study is to identify the policies likely to increase the productivity of arabica coffee producers through a better use of the factors engaged in coffee production, and thus increase producer income. More specifically, the study aims to:

- Estimate the level of technical efficiency of arabica coffee producers, and
- Identify and analyse the variables affecting their technical performance.

This study is of both a practical and theoretical importance. At the practical level, measuring the technical efficiency of coffee plantations, and identifying the factors that affect it, may provide useful information for the formulation of economic policies likely to improve producer technical efficiency. Moreover, from the microeconomic standpoint, identifying the factors that may improve farm profitability is of major significance since, by using information derived from such studies, farms or plantations may become more efficient and hence more profitable.

At the theoretical level, the study aims to bring some contribution to the understanding of producer technical performance in developing countries. In fact, since the introduction of arabica coffee production in 1929, no study to our knowledge has been undertaken to evaluate the technical efficiency level of producers in Cameroon. The results of this study may fill this gap.

2. Cameroon's coffee subsector

Cameroon grows two types of coffee, *Coffea arabica* and *Coffea robusta*. Arabica coffee is cultivated mainly in high altitude areas (between 1,300 and 1,800 m), which in Cameroon are mainly in the West and North-West provinces. According to Ministry of Agriculture (2003) data, arabica coffee farming is carried out on 168,000 farms, mostly small holdings of between 1.0 and 1.2 hectares. Some large European plantations remain in Foumbot. Average arabica coffee yields range from 200 to 900 kg/ha.

Robusta coffee production in Cameroon is highly concentrated in the Moungo area (Littoral Province), which produces 75% of national output, with the second production area being East Province. There are around 190,000 plantations of robusta coffee (Ministry of Agriculture data, 2003). Cultivated areas are generally small, often less than a hectare in East and between 1.0 and 3.0 hectares in the Moungo area. Even though old colonial plantations have been broken up, there still exist a relatively large number of farms (about 10%) that are up to 20 hectares each. In East Province, for example, the agro-industrial domain of the Compagnie Forestière Sangha-Oubangui (CFSO) has a total area of 1,650ha under robusta coffee. Average yields range from 300 to 1,000 kg/ha.

Benefits of coffee production

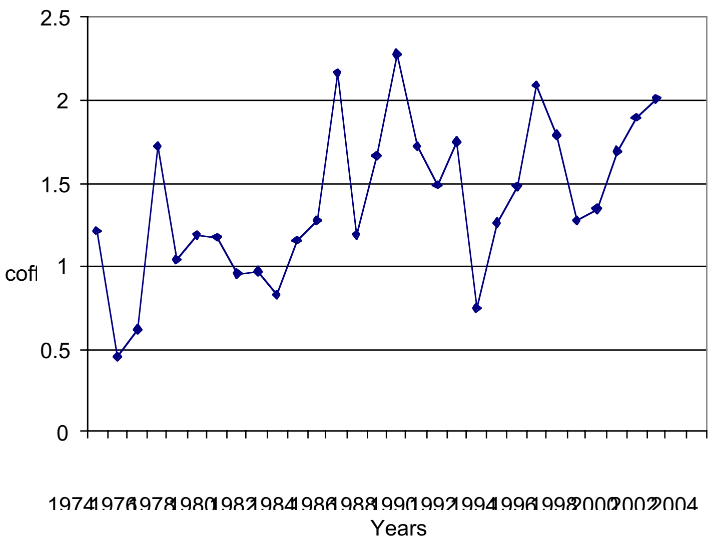
A standing coffee crop has many advantages. At the environmental level, coffee trees of either type maintain a forest-type ecosystem and protect the soil against erosion, thus contributing to the preservation of the environment (Nchare, 2002). At the producer level, it provides financial security to the farmer and represents a realizable asset that can be sold while still green before harvest to satisfy an urgent need for liquidity or serve as collateral for a credit. It may also enhance land tenure security, since its presence on the land testifies to the farmer's ownership rights in case the land is not officially marked out. Moreover, it constitutes an asset that can be passed on to one's offspring (Nchare, 2002).

In terms of rural development, the significance of arabica coffee specifically resides in the fact that it ensures the redistribution of income in rural areas. In 1996/97, about CFAF11 billion were earned by arabica coffee producers. The crop constitutes an important source of income for more than 975,000 persons and contributes significantly to the fight against poverty and the maintenance of social balance in rural areas.

Like many other export crops, arabica coffee earns a share of the foreign exchange necessary to finance the imports of industrial goods, as well as to ensure interest payments on the national debt. At the microeconomic level, arabica coffee is also a very competitive crop. In effect, net income per hectare for arabica coffee is higher than that of either robusta coffee or cocoa: CFAF235,670/ha against CFAF120,000/ha and CFAF90,750/ha, respectively (Nchare, 1999). The evolution of international coffee prices remains favourable to arabica coffee. Figure 1 presents the evolution of the relative prices of arabica and robusta coffee from 1974 to 1998.[3]

With the exception of the periods 1975–1976, 1981–1983 and the year 1993, the c.i.f. (cost, insurance, freight) price of arabica coffee has always been higher than that of robusta coffee, as Figure 1 indicates. On the average, the c.i.f. price per kilogram of arabica coffee is 1.34 times higher than that of robusta coffee during the period considered. Given their requirements in terms of soil and climatic conditions, these crops are grown in different geographic and agro-ecological areas and substitution between them is not possible at the level of the plantation.

Figure 1: Evolution of the relative price of arabica to robusta coffee, 1974–1998



Source : Constructed using data in Appendix Table A1.

Yet, despite the widespread recognition of its significance to Cameroon's economy, the general trend in coffee production has been in decline. Coffee output decreased from 31,663 metric tonnes (MT) in 1974 to 8,243 MT in 2002. This decrease is explained, on the one hand, by the declining productivity of most plantations and specifically for arabica coffee, and on the other hand, by the demographic and economic environment of the coffee production areas.

The fall in productivity in most plantations is due to the poor use of agricultural inputs (fertilizers and pesticides) by farmers, the ageing of most farms, poor handling of crops and the practice of mixed cropping. As for the demographic environment, Cameroon's West and Northwest provinces, where arabica coffee is grown, are the most highly populated, with densities reaching 142 and 102 inhabitants per square kilometre, respectively. Consequently, land constitutes a major input constraint for increasing arabica coffee output in Cameroon.

The economic environment is characterized by a drastic fall in arabica coffee prices, estimated at 50% on the average between 1989 and 1993, coupled with a rise in fertilizer and pesticide prices following the elimination of input subsidies. The major consequence of both of these developments has been the deterioration of the terms of trade for producers.

Evolution of Cameroon's arabica and robusta coffee output

Table 1 presents arabica and robusta coffee output over the 1969–2003 period. From the table we note a constant output increase of arabica coffee between 1969 and 1974, averaging 31,060 MT per year, for an area under cultivation of about 92,640 hectares. Since then, there is a general downward trend in output with average volume dropping to 8,592 MT during the 1999–2003 period. Besides the deterioration of arabica coffee's purchasing power, this fall in output is also explained by a decline in yields and the reduction of areas under cultivation due to the allocation of land to alternative crops (food and vegetable crops).

As for robusta coffee, the data given in Table 1 show that its contribution to total coffee output is more significant than that of arabica coffee (80% against 20% on the average). National output of robusta coffee constantly increased from an average of 61,277 MT during the 1969–1972 period to 99,278 MT during the 1984–1988 period. Output progressively decreased thereafter, mainly because of a decline in the use of chemicals induced by the deterioration of robusta coffee's purchasing power.

Table 1: Evolution of arabica and robusta coffee output, 1969–2003

Periods	Arabica coffee			Robusta coffee			National coffee output	Contribution of each coffee type (%)	
	Average area under cultivation (hectares)	Average output (metric tons) (a)	Average yield (kg/ha)	Average area under cultivation (hectares)	Average output (metric tons) (b)	Average yield (Kg/ha)	(a+b)	Arabica	Robusta
1969-1973	92.640	31.060	335	187.966	61.277	326	92.337	34	66
1974-1978	114.627	24.713	222	197.646	67.107	340	91.820	27	73
1979-1983	114.901	23.202	201	166.689	73.306	439	96.508	24	76
1984-1988	89.411	19.398	222	152.774	99.278	649	118.676	16	84
1989-1993	59.182	11.242	189	147.748	78.320	529	89.562	13	87
1994-1998	42.150	9.898	235	145.017	58.683	405	68.581	14	86
1999-2003	42.112	8.592	204	145.007	49.312	340	57.904	15	85

Sources: Compiled from the statistics of the Ministry of Agriculture, the Cocoa and Coffee Interprofessional Council (CICC), and the National Office of Cocoa and Coffee (ONCC); calculations by the author.

3. Literature review and hypotheses of the study

Several strands of the literature are relevant to our study. First we look at measurements of technical efficiency and methods for identifying the determinants of technical efficiency. Next we consider a sample of empirical results that are relevant to our investigation. Then, from these, we derive the hypotheses of the study.

Measurement of technical efficiency

The efficiency of a firm is its ability to produce the greatest amount of output possible from a fixed amount of inputs. Another way of putting this is to say that an efficient firm is one that given a state of technical know-how, can produce a given quantity of goods by using the least quantity of inputs possible. In fact, the concept of efficiency is derived from a particular interpretation of the notion of production frontier, which in its classical sense is the relationship between output, on the one hand, and the quantity of the inputs used in the production process to obtain that output, on the other. In estimation methods of efficiency frontiers, the production function becomes the production frontier.

The first analyses of efficiency measures were initiated by Farrell (1957). Drawing from Debreu (1951) and Koopmans (1951), Farrell proposed a division of efficiency into two components: technical efficiency, which represents a firm's ability to produce a maximum level of output from a given level of inputs, and allocative efficiency, which is the ability of a firm to use inputs in optimal proportions, given their respective prices and available technology. The combination of these measures yields the level of economic efficiency.

The evaluation of a firm's technical efficiency level results from the estimation of a frontier production function. Two main approaches are used to construct efficiency frontiers. The first of these is the nonparametric approach. In this approach, estimation methods are based on envelopment techniques. Distinct among them are the free disposal hull (FDH) and data envelopment analysis (DEA) methods. The FDH method was developed by Deprins et al. (1984), while the DEA method was initiated by Farrell (1957) and transformed into estimation techniques by Charnes et al. (1978). DEA is based on linear programming and consists of estimating a production frontier through a convex envelope curve formed by line segments joining observed efficient production units. No functional form is imposed on the production frontier and no assumption is made on the error term. Nevertheless, this method is limited because it:

- Lacks the statistical procedure for hypothesis testing.
- Does not take measurement errors and random effects into account; in fact, it supposes that every deviation from the frontier is due to the firm's inefficiency.
- Is very sensitive to extreme values and outliers.

With recent theoretical developments in efficiency analysis, however, methods have been designed to overcome some limitations of DEA. Indeed, a deterministic frontiers statistical theory is now available (Simar and Wilson, 2000). Simar (2003) has proposed a method to improve the performance of DEA/FDH estimators in the presence of noise, while Cazals et al. (2002) developed a robust nonparametric estimator. Instead of estimating the full frontier, they rather propose to estimate an expected maximal output frontier of order *m*. Following this approach, Aragon et al. (2003) developed a new nonparametric estimator of the efficiency frontier based on the conditional quantiles of an appropriate distribution associated with production processes. Unfortunately, this method is not extended to multivariate analyses.

The second approach is the parametric approach. It is based on econometric estimation of a production frontier whose functional form is specified in advance. In this approach, the stochastic frontiers method is the most popular. Also referred to as "composed error model", the stochastic frontiers method has the advantage of taking into account measurement errors or random effects. Criticism of this method resides in the need to specify beforehand the functional form of the production function and the distributional form of the inefficiency term.

The stochastic frontiers method is used in this study. We make this choice on the basis of the variability of agricultural production, which is attributable to climatic hazards, plant pathology and insect pests, on the one hand, and, on the other hand, because information gathered on production is usually inaccurate since small farmers do not have updated data on their farm operations. In fact, the stochastic frontiers method makes it possible to estimate a frontier function that simultaneously takes into account the random error and the inefficiency component specific to every plantation.

The stochastic frontiers production method was proposed for the first time by Aigner et al. (1977) and Meeusen and Van den Broeck (1977). It is defined by equation:

$$\ln y_j = f(x_{ij};\beta) + \varepsilon_j \qquad (1)$$

where y_j is the farm's output j, x_{ij} is the vector of quantities of factors of production i used by farm j and $\hat{a}$ is a vector of unknown parameters. $\mathring{a}_j$ is an error term $(u_j \geq 0, \forall_j)$ composed of two independent elements, i.e., $\mathring{a}_j = í_j - u_j$, where $í_j$ is a stochastic variable with zero mean and unknown variance $ó^2_í$, u_j is the non negative stochastic term representing technical inefficiency in production of farm j; its mean is m_j and its variance is $ó^2_u$.

By following different parameterizations such as those of Battese and Corra (1977), Battese et al. (1988), and Battese (1992), the likelihood function of the model defined by Equation 1 can be written:

$$\ln(L) = -\frac{N}{2}\left(\ln\left(\frac{\pi}{2}\right) + \ln\sigma^2\right) + \sum_{j=1}^{N}\ln\left[1 - \Phi\left(\frac{\varepsilon_j\sqrt{\gamma}}{\sigma\sqrt{(1-\gamma)}}\right)\right] - \frac{1}{2\sigma^2}\sum_{j=1}^{N}\varepsilon^2 \qquad (2)$$

with $\mathring{a}_j = \ln y_j - f(x_{ij};\hat{a})$, $\mathring{a}_j$ is the residual of Equation 1, N is the number of observations, $Ö(.)$ is the standard normal distribution function, and $ó^2 = ó^2_í + ó^2_u$ and $ã = ó^2_u/ó^2_í$ are variance parameters. By assuming a half-normal distribution of u_j, mean technical efficiency can be computed as follows:

$$E\left[\exp\left(-u_j\right)\right] = 2\left[1 - \Phi\left(\sigma\sqrt{\gamma}\right)\right] * \left[\exp\left(-\gamma\sigma^2/2\right)\right] \tag{3}$$

Moreover, the measurement of technical efficiency (or inefficiency) level of farm *j* requires estimating the random term u_j. Considering the assumptions made on the distribution of u_j and í$_j$ Jondrow et al. (1982) first compute the conditional mean of u_j given å$_j$. Battese et al. (1988) derive the best indicator of farm *j* technical efficiency, written as $TE_j = exp(-u_j)$ using the formula:

$$E\left[\exp\left(-u_j\right)/\varepsilon_j\right] = \left[\frac{1-\Phi\left(\sigma_A + \gamma\varepsilon_j/\sigma_A\right)}{1-\Phi\left(\gamma\varepsilon_j/\sigma_A\right)}\right]\left[\exp\left(\gamma\varepsilon_j + \sigma_A^2/2\right)\right] \tag{4}$$

where $\sigma_A = \sqrt{\gamma(1-\gamma)\sigma^2}$.

Methods for identifying technical efficiency determinants

In the literature, two main approaches are used to analyse the determinants of technical efficiency from a stochastic frontier production function. The first approach, called the two-step approach, first estimates the stochastic frontier production function to determine technical efficiency indicators. Next, indicators thus obtained are regressed on explanatory variables that usually represent the firms' specific characteristics, using the ordinary least square (OLS) method. This two-step approach has been used by authors such as Pitt and Lee (1981), Kalirajan (1981), Parikh, Ali and Shah (1995), and Ben-Belhassen (2000) in their respective studies.

The major drawback with the two-step approach resides in the fact that, in the first step, inefficiency effects (u_j) are assumed to be independently and identically distributed in order to use the Jondrow et al. (1982) approach to predict the values of technical efficiency indicators. In the second step, however, the technical efficiency indicators thus obtained are assumed to depend on a certain number of factors specific to the firm, which implies that the u_j's are not identically distributed unless all the coefficients of the factors considered happen to be simultaneously null.

After becoming aware that the two-step approach displayed these inconsistencies, Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991) developed a model in which inefficiency effects are defined as an explicit function of certain factors specific to the firm, and all the parameters are estimated in one step using the maximum likelihood procedure. By following this second approach Huang and Liu (1994) developed a non neutral stochastic frontier production function, in which the technical inefficiency effects are a function of a number of factors specific to the firm and of interactions among these factors and input variables introduced in the frontier function. Battese and Coelli (1995) also proposed a stochastic frontier production function for panel data in which technical inefficiency effects are specified in terms of explanatory variables, including a time trend to take into account changes in efficiency over time. By following the one-step approach the model of technical inefficiency effects is specified in the following manner:

$$u_j = z_j^{\delta} + w_j \quad (5)$$

where Z_j is the vector of characteristics specific to farm j, d is a vector of parameters to be estimated, and W_j is the random terms assumed to be independently and identically distributed. It is defined by the truncation of the normal distribution with zero mean and unknown variance $ó^2_w$, such that u_j is non negative (i.e., $W_j \oplus - Z_j\delta$).

The one-step approach has since been used by such authors as Ajibefun et al. (1996), Coelli and Battese (1996), Audibert (1997), Battese and Sarfaz (1998), and Lyubov and Jensen (1998) in their respective studies to analyse the factors affecting the technical efficiency (or inefficiency) of agricultural producers.

We use the one-step approach in this study. In effect, relative to the two-step approach, the one-step approach presents the advantage of being less open to criticism at the statistical level, and helps in carrying out hypothesis testing on the structure of production and degree of efficiency.

A few empirical results

By applying their model of technical inefficiency effects using panel data on Indian paddy rice producers, Battese and Coelli (1995) found a positive relationship between the degree of inefficiency and the producer's age, and a negative relationship between the degree of inefficiency and the educational level of the producer. Coelli and Battese (1996) used the same approach to analyse the factors affecting the technical inefficiency of Indian farmers, and found the mean technical efficiency levels to be 0.74 and 0.71, respectively, for the villages of Aurelle Kanzara and Shirapur. They also found a negative correlation between technical inefficiency and variables such as farm size and the level of education and age of the farmer.

By using the translogarithmic stochastic frontier production function in which inefficiency effects are a function of socioeconomic variables, Ajibefun et al. (1996) obtained technical indicators whose average was 82%. They found positive correlations between the degree of technical inefficiency and the farmer's age, farm size and proportion of hired labour used, and a negative correlation between the degree of technical inefficiency and the producer's experience. Lyubov and Jensen (1998) used the same approach as Ajibefun et al. (1996) to analyse the technical efficiency of grain production in the Ukraine from 1989 to 1991. Out of the 80 farms considered, they found that variables such as the number of farm workers per hectare, the proportion of active household members engaged in non-agricultural activities, and the distance between the farm and the nearest city, have a negative impact on technical inefficiency.

Technical inefficiency of maize farmers' productivity in Eastern Ethiopia, according to Seyoum et al. (1998), is a decreasing function of the farmers' educational level and the number of hours of instruction received by those farmers who participated in the extension service's modern technology project. For farmers still using traditional production methods, however, the level of education did not significantly affect technical efficiency.

In his study on the measurement and explanation of technical efficiency in hog production in the state of Missouri in the USA, Ben-Belhassan (2000) used the two-step approach described above and concluded that farmers' educational level and experience had a positive influence on technical efficiency. He also found the average level of technical efficiency to be 82%.

Weir (1999) and Weir and Knight (2000) investigated the impact of education on technical efficiency in Ethiopia and found that household education positively influences the level of technical efficiency in cereal crop farms.

An analysis of the productive performance of robusta coffee farmers in a low income area in Côte d'Ivoire also used the two-step approach (Nyemeck et al., 2001). Instead of adopting the parametric approach, these authors used the DEA method to calculate technical efficiency indexes. Furthermore, the efficiency indexes obtained were regressed on the set of socioeconomic variables with the help of double censure Tobit model. They determined that belonging to a mutual aid group and family size negatively and significantly affect the level of technical efficiency. The efficiency indexes they calculated varied between 2% and 100%, with a mean of 36%.

Helfand (2003) used the same approach as Nyemeck et al. (2001) to explore the determinants of productive efficiency in the Brazilian Center-West. From the results of his research, it is clear that access to credit institutions and to goods supplied by the public sector such as electricity and technical assistance, the use of modern inputs like fertilizers, and the practice of irrigation, soil conservation and crop protection against pests are the factors responsible for differences in the level of inefficiency between plantations.

It emerges from the foregoing brief review of empirical studies that farmers, in general, allocate their productive resources inefficiently. From 18% to as much as 64% of agricultural output is lost because of inefficiencies specific to the farms, depending on the different studies. Moreover, there are many socioeconomic variables that influence the technical efficiency of farmers. Personal characteristics include the farmer's age, level of education and experience. Among other immediate factors are farm size, family size, number of farm workers per hectare, distance between the farm and the nearest city, and the proportion of active household members engaged in non-farm activities. Additional influences are access to credit institutions and to goods supplied by the public sector such as electricity and technical assistance, the use of modern inputs like fertilizer, and the practice of irrigation, soil conservation and crop protection against pests. In fact, the studies reveal that it is possible to increase agricultural production significantly, simply by improving the level of producer technical efficiency without additional investments.

Hypotheses of the study

On the basis of the literature reviewed above and personal knowledge of the subject, the following null hypotheses were formulated for this study:

- Cameroonian arabica coffee farmers are technically efficient. In other words, this hypothesis stipulates that no productivity gains linked to the improvement of technical efficiency may be realized in coffee production.

- The age, educational level and experience of farmers, membership in a mutual aid group, family size, agricultural extension workers' contact with coffee plantations, accessibility to credit, use of the coffee Java variety, and the practice of mono-cropping do not significantly influence the farmer's technical efficiency.

Table 2: Summary of the results of a few empirical studies reviewed

Authors	Title of the study	Analytical method	Results	
			Mean technical efficiency (%)	Determinants of technical efficiency
Coelli and Battese, 1996	Identification of factors that influence the technical inefficiency of Indian farmers	Stochastic frontier (panel)(one-step approach)	73	Farm size, farmer's age and educational level
Ajibefun, Battese and Daramola, 1996	Investigation of factors influencing the technical efficiencies of smallholder croppers in Nigeria	Stochastic frontier (one-step approach)	82	Farm size, farmer's age; proportion of hired labour used
Lyubov and Jensen, 1998	Technical efficiency of grain production in Ukraine	Stochastic frontier (panel) (one-step approach)	NC	Farm workers/ hectare, distance from farm to nearest city
Seyoum et al., 1998	Technical efficiency and productivity of maize producers in eastern Ethiopia: A study of farmers within and outside the Sasakawa-global 2000 project	Stochastic frontier (one-step approach)	NC	Educational level of farmers who participate in project activities
Ben-Belhassan, 2000	Measurement and explanation of technical efficiency in Missouri hog production	Two-step approach (parametric)	82	Nature of technology used; farmer's managerial skills
Weir and Knight, 2000	Education externalities in rural Ethiopia: Evidence from average and stochastic frontier production functions	Stochastic frontier (one-step approach)	55	Household educational level
Nyemeck et al., 2001	Analyse des déterminants de la performance productive des producteurs de café dans une zone à faible revenu en Côte d'Ivoire	Two-step approach (DEA and econometric model)	36	Belonging to a mutual aid-group and family size
Helfand, 2003	Farm size and determinants of productive efficiency in the Brazilian Centre-West	Two-step approach (DEA and econometric model)	NC	Access to credit, institutions, and modern inputs

NC = not computed

Source: Compiled by author.

4. Methodological framework

Recognized influences on technical efficiency, both farm and farmer specific, become the basis of the stochastic frontier production function used in this study. The function is summarized in the following:

$$\ln Y_j = \beta_0 + \sum_{i=1}^{6} \beta_i \ln X_{ij} + \frac{1}{2}\sum_{i=1}^{6}\sum_{k=1}^{6} \beta_{ik} \ln X_{ij} \ln X_{kj} + v_j - u_j \qquad (6)$$

where *ln* designates a natural logarithm and subscripts *i* and *j*, respectively, represent the inputs *i* used by farm *j*. Further:

- Y = the value of agricultural output harvested on the given farm (in CFAF)[4]
- X_1 = the total area planted with coffee (in hectares)
- X_2 = the amount of labour, which includes both family and hired labour (in person-days)
- X_3 = the total quantity of chemical fertilizers used in coffee plantations (in kg)
- X_4 = the cost of pesticides used in coffee production (in CFAF)
- X_5 = the age of coffee tree (in years)
- X_6 = the capital, i.e., the amount of depreciation of agricultural equipment used in coffee production (in CFAF)

Finally, $í_j$ represents the random variable with zero mean and unknown variance $ó^2_i$ and u_j is the non negative random term $(u_j \geq 0, \forall_j)$ representing the technical inefficiency in production of farm *j*. It is assumed to be independently and identically distributed between observations, and is obtained by truncation at point zero of the normal distribution with mean u_j, and variance $ó^2_u$, where the mean is defined by the equation:

$$\mu_j = \delta_0 + \delta_1 \mathrm{AP} + \delta_2 \mathrm{NEP}_j + \delta_3 \mathrm{EXP}_j + \delta_4 \mathrm{T}F_j + \delta_5 \mathrm{N}VA_j + \delta_6 DAC_j$$
$$+ \delta_7 DGE_j + \delta_8 DVC_j + \delta_9 DSC_j + \delta_{10} DIST \qquad (7)$$

where:

- *AP* = the age of the farm manager (in years)
- *NEP* = the producer's level of education measured in number of years of schooling
- *EXP* = producer's experience measured in number of years spent in producing coffee
- *TF* = family size, i.e., number of persons living with the household for more than six months in a year, including the farm manager

NVA = number of visits to the coffee farm by extension service agents
DAC = dummy variable indicating if the farmer has access to credit: yes = 1 no = 0
DGE = dummy variable indicating if the farmer belongs to a mutual aid group: yes = 1, no = 0
DVC = dummy variable indicating the coffee variety planted: Java variety = 1, other varieties = 0
DSC = dummy variable representing the system of cultivation used: mono-cropping = 1, mixed cropping = 0
DIST = distance between the producer's house and the coffee plots

The use of the value of output as an endogenous variable rather than the physical quantities of products is justified by the fact that some producers practice mixed cropping in which banana, plantain and coffee trees are grown at the same time on the same piece of land. Given the problems linked to aggregating the physical quantities of bananas, plantains and coffee to obtain the total output of the coffee plot, we have chosen to use the CFA franc as a numeraire to get the value of the harvested outputs. Moreover, some exogenous variables are also expressed in value terms. This does not cause any statistical problem since the endogenous variable is also expressed in value terms. Actually, the approach used here is largely drawn from the studies of such authors as Ajibefun et al. (1996), Battese and Coelli (1995), Coelli and Battese (1996), Bravo-Ureta and Pinheiro (1997), and Coelli et al. (1998), who used the same conversion method in their respective studies in situations where farmers practised mixed cropping systems of cultivation.

The introduction of the coffee tree's age in the production function permits us to capture its biological cycle: The young coffee plant grows for three to four years before bearing fruit. Full production starts in the ninth year and lasts until the twentieth year, when a progressive decline begins (Rourke, 1970).

Equation 7 constitutes the technical inefficiency effects model in the stochastic frontier of Equation 6. Considering the stochastic frontier production function defined by Equation 6, the technical efficiency of farm *j*, written as TE_j, is defined according to Battese et al. (1988) as:

$$TE_j = \exp(-u_j) \tag{8}$$

TE_j always takes on values between 0 and 1. A value of 1 indicates that farm *j* displays complete technical efficiency, whereas a value close to zero reveals the degree of inefficiency of the farm considered. In effect, the TE_j indicator, usually interpreted as a measure of managerial efficiency, is an expression of the farmer's capacity to achieve results comparable to those indicated by the production frontier.

In the model represented by equations 6 and 7, the coefficients $â_0$, $â_i$, $â_{ik}$ and $ä_0$ to $ä_{10}$ and the variance parameters $ó^2 = ó^2_i + ó^2_u$ and $ã = ó^2_u/ó^2_i$ are simultaneously estimated by maximum likelihood method, using *Frontier* 4.1 software developed by Coelli (1996).

The model of the stochastic frontier production function in Equation 6 is a development of the original stochastic frontier production function proposed by Aigner et al. (1977) and Meeusen and Van den Broeck (1977) in which technical inefficiency effects are modelled in terms of the other variables, as proposed by Battese and Coelli (1995) for panel data.

To study returns to scale in arabica coffee production, the scale coefficient *(á)* has been calculated. By definition, returns to scale are measured by the sum of partial output elasticities with respect to each input. In this study, the mean value of the farm's output elasticity with respect to each input is estimated using the following formula:

$$\left(\frac{\partial \ln E(Y_j)}{\partial \ln(X_k)}\right) = \beta_k + 2\beta_{kk} \ln(X_{ki}) + \sum_{j \neq k} \beta_{kj} \ln(X_{ji}) \tag{9}$$

Thus, the scale coefficient (α) is given by:

$$\alpha = \sum_{k=1}^{n} \left(\frac{\partial \ln E(Y_i)}{\partial \ln(X_k)}\right) \tag{10}$$

The magnitude of *á* measures the proportional change in output resulting from a unit proportional increase in all inputs. The industry exhibits increasing returns to scale if *á* is greater than one, constant returns to scale if *á* equals one, and decreasing returns to scale if *á* is less than one.

In order to verify the hypotheses of this study and to choose between the Cobb–Douglas and translog functional forms the one that best represents the data, we carry out the generalized likelihood-ratio test (LR). The LR test statistic (*ë*) is calculated as follows:

$$\lambda = -2 \ln\left[L(H_0)/L(H_1)\right] \tag{11}$$

where $L(H_0)$ and $L(H_1)$ are, respectively, the values of the likelihood functions derived with and without constraints imposed by the null hypothesis (H_0), H_1 being the alternative hypothesis. If the null hypothesis is accepted, *ë* has a Chi-square (or mixed Chi-square) distribution with a number of degrees of freedom equal to the difference between the number of estimated parameters under H_1 and H_0.

5. Data collection and sampling

This study uses data on the technical coefficients (inputs–outputs) of arabica coffee production and socioeconomic characteristics of farmers. The data include all factors of production (land, labour, fertilizers, pesticides, capital) used in coffee production and their respective costs, as well as arabica coffee yields, output sold, sale prices, transport costs up to sales outlets and other marketing costs.

For socioeconomic variables, the data gathered comprise: the producer's age, level of education, experience in coffee production and membership in a mutual aid group, family size, number of visits to coffee plantation by agricultural extension agents, use of chemical fertilizer on coffee, use of the improved variety of coffee called Java, and the practice of mono-cropping.

The data were collected during the 2004 crop year.

Sampling

West and North-West provinces of Cameroon were the focus of this study because these two provinces contribute 69% and 31%, respectively, to national arabica coffee output. Within these provinces, the selection of divisions took into account the importance of their contribution to the total output of the region. Thus, the Menoua, Banboutos, Mifi, Bui and Mezam divisions were chosen for the survey. According to the calculations carried out, these five divisions contribute more than 75% of the total arabica coffee output in Cameroon.

The target population for the study was exclusively made up of those arabica coffee producers who figured in the records of MINAGRI's Statistics Services. Considering the time available, the total sample size of the study was limited to 150 farmers. Using MINAGRI's data on producers' characteristics and coffee output, the number of survey producers per division was computed according to the formula developed by Snedecor and Cochrane (1980).

$$n_h = n * \frac{N_h S_h}{\sum N_h S_h} \tag{12}$$

where n_h is the sample size of arabica coffee producers in division h and n is the total sample size. In the present study, $n = 150$. N_h is the number of coffee producers counted in division *h*, and S_h is the standard deviation of coffee output per farm in division *h* (see Table 3 for details of the distribution of the sample).

Table 3: Distribution of arabica coffee producers' samples per division

Province	Division	Number of producers counted in MINAGRI census (N_h)	Average output (Kg/farm) 1992–1994	Standard deviation (S_h)	Sample size per division (n_h)
North-West	Bui	20,927	89	83	21
	Mezam	13,779	110	158	26
West	Bamboutos	18,136	216	162	35
	Ménoua	20,698	240	171	42
	Noun	6,613	309	328	26

Source: Compiled by the author from the agricultural statistics of the Ministry of Agriculture, 1995.

At the level of the divisions selected, the choice of villages for the survey was done on the basis of the importance of their total coffee production in the division. This selection was carried out in collaboration with the heads of Divisional Services and MINAGRI extension workers (MEWs) in the production area.

Selection of producers and administration of the questionnaire

From the records of MINAGRI's Statistics Services, we proceeded with a systematic draw to get farmers to serve as our targets for the study. Through this drawing without replacement technique, we were able to get a representative sample of arabica coffee farmers in Cameroon.

The questionnaire was administered by the author with the help of five survey researchers recruited among MEWs. The MEWs were chosen as survey researchers because they not only have a good knowledge of rural areas, they are also well known to the farmers. Moreover, they had previously been trained in survey methods and given some appropriate equipment (i.e., decametres, scales and calculators) to measure areas and outputs.

Field data were collected from the statements of farmers and by direct measurement. Prior to an interview, the objective and aims of the survey were clearly explained to the interviewee. In every farm, the head of the household, who is considered as the farm manager, was interviewed first before proceeding to the partner or children.

At the end of the interview in every zone, the questionnaires collected were checked to ensure the coherence and consistency of the information gathered. For questionnaires that were wrongly filled, researchers went again in the field to try to verify and correct the incoherence or inconsistency therein.

In all, 150 farmers were surveyed. However, the analysis was carried out with data on only 140 farmers because of inconsistencies and lack of coherence in some of the data collected.

Measurement of variables

As noted earlier, the value of produce harvested from the farm is used here instead of the physical quantity because some farmers practised mixed cropping in which more than one crop is grown on a piece of land at the same time. This value is obtained by multiplying the quantities of products harvested on the plot by the farm-gate price. In effect, when the farmer sells products on the market, transport and other marketing costs are subtracted from the market price to find the farm-gate price. Farm-gate prices of self-consumed products correspond to the purchase price on the village market, to which transport costs up to the farm are added. As to the land variable, it is measured by the area under coffee cultivation.

Concerning labour, calculations were made by choosing the person-day as the base unit (for family and hired labour) and weighting it according to the Food and Agriculture Organization (FAO) method. For a woman, working hours are multiplied by 0.75 and for children below 15 years, the coefficient is 0.5. Finally, working hours are determined in person-days by dividing actual working hours by eight. It should be noted that a person-day of work corresponds to eight hours of work per day.

For the fertilizer variable, the quantity registered corresponds to the one that was applied on the coffee trees in the course of the 2003 crop year, since the impact of this input on production is only felt one year after its application.

As for capital, the value of agricultural equipment is used if its economic life is less than one year. For tools whose economic life is more than one year, the depreciation charges are calculated according to the rate of straight-line depreciation recorded in the course of time. In this respect, the cost of agricultural equipment is divided by its economic life to obtain its annual use cost. The cost of pesticides is equal to the quantity used multiplied by the purchase price, to which is added the cost of transportation to the plantation.

The producer's educational level and experience are determined by the number of years spent in school and in coffee farming. Family size is determined by the number of people living in the household during the 2004 crop year. Agricultural extension workers' contact with the farms is calculated through the number of visits paid to plantations during the 2004 crop year. Table 4 summarizes the descriptive statistics for arabica coffee producers.

From Table 4, the value of output per farm is CFAF294,718 for a cultivated area of 1.45ha. The average quantity of labour used is estimated at 176 person-days. Fertilizer is used extensively, with an average consumption of 181kg. In addition, it is worth noting that these two inputs, land included, are the main factors of arabica coffee production. The amount of capital is CFAF9,777 on the average. The low depreciation value of agricultural equipment is proof of the high use of labour in the coffee farms. However, one of the problems in arabica coffee production in Cameroon is the ageing of both the plantations and the farmers. Here we find that the average ages of plantations and farmers are 27 and 48 years, respectively. In addition, coffee is cultivated together with other food crops by 65% of the farmers interviewed and only 42% of them planted the Java variety. Moreover, 59% of farmers had access to credit and 56% belong to mutual aid groups.

Table 4: Descriptive statistics for arabica coffee producers

Variables	Units	Sample mean	Standard deviation	Minimum	Maximum
Value of output	CFAF	294,718	246,873	41,300	975,800
Land	Hectare (ha)	1.45	0.61	0.62	3.32
Labour	Person-day	176	155	17	570
Fertilizer	Kilograms (kg)	181	171	15	1.200
Pesticides	CFAF	10,559	8,882	1,240	36,000
Age of coffee tree	Years	27	5	18	33
Capital	CFAF	9,777	6,040	2,480	34,128
Age of producer	Years	48	7	23	62
Educational level of producer	Years	6	2	1	13
Experience of producer	Years	24	6	5	38
Family size	Number of people living together in the home	11	3	5	18
Contact with extension workers	Number of visits	3	1	1	4
Distance between house and coffee plot	Kilometres (km)	0.247	0.337	0.010	1.300
Access to credit		0.59	0.49	0	1
Membership in a mutual aid group		0.56	0.50	0	1
Variety of coffee planted		0.42	0.49	0	1
System of planting developed		0.35	0.41	0	1

Source: Study results.

6. Empirical results

This section focuses on three areas of concern. The first is the parameters estimated for the stochastic frontier production function and the efficiency indexes obtained. The second is the test of the hypotheses of the study and the third centres on the analysis of technical inefficiency determinants.

Parameters estimated of the stochastic frontier production function

In choosing a model that adequately represents the data, we estimated two functional forms (Cobb–Douglas and translog), and then tested the assumption according to which the Cobb–Douglas (1928) functional form is an adequate representation of data, given the specifications of the translog model. This boils down to testing the null hypothesis according to which the second order coefficients of the translog functional form are simultaneously null.

It emerges that the value of the generalized likelihood-ratio statistic for testing the null hypothesis, that the second-order parameters in the translog production frontier function have zero values (H_0: $\hat{a}_{jk}=0, j\leq k=1,2,3,4,5,6$), is 133.76. This value exceeds the critical Chi-square value of 32.67 at 5% level of significance, with 21 degrees of freedom. Consequently, the null hypothesis according to which the second order coefficients of the translog functional form are simultaneously null is rejected at the 5% significance level. Thus, the Cobb–Douglas functional form is not an adequate representation of the data. Appendix Table A2 shows the parameters of the translog production frontier function estimated through the maximum-likelihood method.

Partial elasticities and returns to scale

Considering that some individual coefficients of the variables of the translog stochastic frontier production function are not directly interpretable because of the presence of second order coefficients, partial elasticities of output with respect to inputs are estimated because they permit the evaluation of the effect of changes in the amount of an input on the output. Table 5 shows the results obtained.

The partial elasticity values obtained indicate the relative importance of every factor used in coffee production. In fact, from Table 5 it can be observed that fertilizer is an important factor in coffee production, followed by capital, land, pesticides and labour.

The scale coefficient is 1.25. This value is greater than one, indicating increasing returns to scale in coffee production. The implication of such a result is that a proportional increase of all the factors of production leads to a more than proportional increase in production. This result further reveals that coffee farmers can benefit from the economies of scale linked to increasing returns in order to boost production. Similar results were obtained by Ajibefun et al. (1996) and Ajibefun and Daramola (2004) in their respective studies in Nigeria.

Table 5: Partial elasticity and returns to scale of arabica coffee inputs

Variable	Partial elasticity
Land	0.19
Labour	0.04
Fertilizer	0.53
Pesticides	0.06
Capital	0.44
Returns to scale	1.25

Source: Study results.

In addition, the value estimated for the variance parameter g of the translogarithmic stochastic production frontier function is not only very close to one, but is also significantly different from zero. This finding reveals some technical inefficiencies in coffee production.

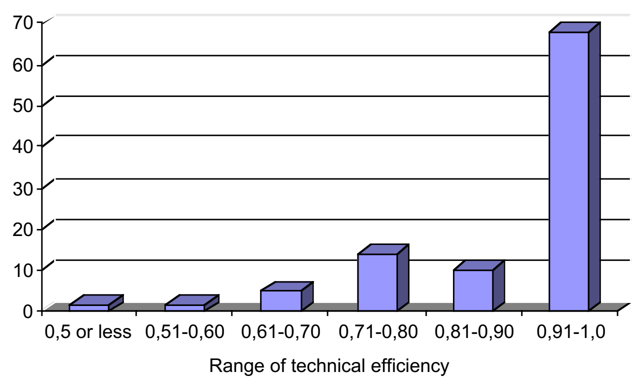
The variable "age of coffee trees" is negative and significant at the 5% level. It confirms the coffee tree's biological cycle.

Description of farmers' technical efficiency indexes

The efficiency indexes obtained are grouped together in Appendix Table A2. They vary from one farmer to another in a range from 0.24 to 0.98, with an average of 0.90. According to these results, 10% of coffee output on the average is lost due to the specific inefficiencies pertaining to farms. In addition, the level of mean technical efficiency obtained falls in line with results obtained by Battese et al. (1989), Dawson and Lingard (1989), Kouadio and Pokou (1991), and Squires and Tabor (1991) in their respective studies. Figure 2 presents the frequency distribution of the efficiency indexes estimated.

From Figure 2, it can be observed that a good number of the farmers interviewed (about 68%) have technical efficiency indexes between 0.91 and 1.0, and 32% have

Figure 2: Frequency distribution of the technical efficiency of coffee producers



Source: Constructed using data from Appendix Table A3.

indexes of less than 0.91. These findings reveal the presence of technical inefficiencies whose elimination could lead to the improvement of the technical efficiency of arabica coffee farmers. In addition, the frequency distribution of efficiency indexes indicates high technical efficiency variations among producers.

Tests of hypotheses

To verify the null hypotheses of the study, the generalized likelihood ratio test was used. The results are presented in Table 6 in which the second order coefficients of the translogarithmic stochastic frontier production functional form are equal to zero is rejected at the 5% level of significance. Consequently, the Cobb–Douglas functional form is not an adequate representation of data. The same thing obtains for the null hypothesis according to which Cameroonian arabica coffee producers are technically efficient (γ=0).

Table 6: Tests of hypotheses for parameters of the translogarithmic stochastic frontier production function and technical inefficiency model

No.	Null hypothesis	Ln (Likeli-hood) function	Test statistic (λ)	D.F.	Critical value	Decision
Production function						
1.	H_0: â$_{jk}$=0, j≤k=1,2,3,4,5,6	94.58	133.76	21	32.67	Reject H_0
Inefficiency model						
2.	H_0: γ=0	84.53	154.00	12	20.41[a]	Reject H_0
3.	H_0: ä$_1$=ä$_2$….=ä$_{10}$=0	110.49	101.94	10	18.31	Reject H_0

[a]If the null hypothesis H_0 : g =0 is true, this implies that the explanatory variables of the technical inefficiency effects model are not identified. Consequently, the critical value of the test statistic is obtained from Kodde and Palm (1986: 1246, Table 1) at q+1 degrees of freedom, and at the 5% level of significance.

Source: Study results.

The null hypothesis, which specifies that the age, educational level and experience of farmers, membership in a mutual aid group, family size, agricultural extension workers' contact with the coffee plantation, accessibility to credit, use of the Java variety, and mono-cropping do not significantly influence the farmer's technical inefficiency, is also rejected at 5% level of significance. In fact, this last result indicates that the joint effects of all the explanatory variables on the productive inefficiencies are important even if some of them are not statistically different from zero.

Determinants of technical inefficiency of coffee producers

Although the assessment of the degree of efficiency is important, one cannot count on it. In order to make recommendations for economic policies, it is necessary to identify the source of variation in technical efficiency between farmers. In this light, the inefficiency effects model is estimated. Table 7 presents the results.

Table 7: Estimated parameters of the inefficiency effects model

Variable	Parameter	Coefficient estimate	Standard error	t-ratio
Constant	δ_0	0.381	0.406	0.938
Age	δ_1	0.002	0.009	0.210
Educational level of producer	δ_2	-0.057**	0.031	-1.857
Experience of producer	δ_3	0.006	0.012	0.549
Family size	δ_4	0.005	0.013	0.383
Contact with extension workers	δ_5	-0.026	0.034	-0.749
Access to credit	δ_6	-0.316**	0.140	-2.257
Membership in mutual aid group	δ_7	0.023	0.065	0.348
Variety of coffee planted	δ_8	0.024	0.106	0.226
System of planting developed	δ_9	-0.152	0.105	-1.444
Distance between house and coffee plot	δ_{10}	0.213	0.143	1.490

** Significant at 5% level.
Sources: Study results.

In contrast to the results obtained by Nyemeck et al. (2001) on the determinants of the productive performance of robusta coffee producers in Côte d'Ivoire, Table 7 shows that the educational level of producers and access to credit are the main socioeconomic variables that significantly affect the technical inefficiency of farmers.

The educational level has a negative and significant effect on technical inefficiency. This result shows that farmers who have spent many years in formal education tend to be more efficient in coffee production. Similar results were obtained by Belbase and Grabowski (1985), Ali and Flinn (1987), Bagi (1987), Durasaimy (1990), Pinheiro (1992), Seyoum et al. (1998), Weir (1999), and Weir and Knight (2000).

Access to credit also has a negative influence on technical inefficiency. Actually, it reduces the financial difficulties farmers face at the beginning of the crop year, thus enabling them to buy inputs. This result is also similar to those obtained by Bravo-Ureta and Evenson (1994), Kalirajan and Shand (1986), and Obwona (2005).

With the exception of the aforementioned two variables, the farm manager's age, experience in coffee production and membership in a mutual aid group, along with contact with agricultural extension workers, family size, the use of the improved Java variety of arabica coffee, the distance between house and coffee plots, and the practice of mono-cropping are not significantly different from zero at the 5% level as indicated in Table 7. Nevertheless, the variable signs such as the age of the farmer, contact with extension workers, the practice of mono-cropping, and the distance between house and coffee plots are in accordance with the expectations.

The coefficient estimated for the age variable has a positive sign, implying that old farmers are technically more inefficient than younger ones. This result can be explained in terms of adoption of modern technologies. According to some authors such as Hussain (1989), older farmers are less likely to have contact with extension workers and are equally less inclined to adopt new techniques and modern inputs, whereas younger farmers, by virtue of their greater opportunities for formal education, may be more skilful in the search for information and the application of new techniques. This, in return, will improve their level of technical efficiency.

The coefficient estimated for the variable indicating contact with extension workers has a negative sign, implying that the technical inefficiency diminishes with the number of visits made to the plantation by extension workers. Actually, regular contacts with these workers facilitate the practical use of modern techniques and adoption of agronomic norms of production. In analysing the impact of extension services on agricultural production in Zimbabwe, Owen et al. (2001) found that farmers' access to extension services increases the value of their output by 15%.

There is also a negative correlation between technical inefficiency and the mono-cropping system. This result may be explained by the fact that the mono-cropping system not only enables farmers to work tirelessly, but also saves the coffee plants from the competition that might occur among various crops in case of mixed cropping for the use of inputs available at the farm level. Besides, this result falls in line with the technical recommendations of the MINAGRI. Considering the agronomic requirements of coffee plants, extension agents generally advise farmers to adopt the mono-cropping system for the plant.

On the other hand, a positive correlation exists between family size and technical inefficiency, implying that any improvement or increase in the value of this variable entails a rise in productive inefficiencies. This is explained by the abundance of available labour at the farm level. In point of fact, arabica coffee production areas are among the most populated in Cameroon with an average of ten persons per household (Nchare, 2002).

Similarly, technical inefficiency and the coffee variety planted are positively correlated. This result is contrary to expectations. In effect, following the CFA franc devaluation, whose immediate consequence in the agricultural sector was the doubling of the nominal prices of imported chemical inputs (fertilizers and pesticides), coffee producers were forced to reduce the application of these inputs to their crop even though the improved Java variety of arabica coffee they had planted requires relatively significant quantities of chemical inputs to be productive.

Moreover, the estimated coefficient of the variable representing the producer's experience indicates that inefficiency increases with the number of years spent in coffee production. In effect, descriptive statistics show that arabica coffee is grown by ageing producers (48 years old on the average), while the number of years spent in coffee production averages 24 years per farmer. This ageing of producers has harmful consequences for the recommended cultural methods and consequently for the productivity of coffee plantations.

Finally, we also note a positive correlation between technical inefficiency and the distance separating the producer's house and coffee plots. This result is explained by the fact that in Cameroon, living quarters are situated within coffee plantations, which enhances the producer's land tenure security by testifying to ownership rights in case the land is not officially marked out. In fact, coffee plantations are not a long way from producers' houses.

7. Conclusions, policy implications and limitations of the study

The objective of this study was to analyse the factors that influence the technical efficiency of arabica coffee farmers in Cameroon. To achieve this objective, the translogarithmic stochastic frontier production function is estimated using the maximum likelihood method. The inefficiency effects are specified to be functions of the age, educational level and experience of the farmer, membership in a mutual aid group, family size, the contact of the coffee plantation with extension workers, access to credit, the use of the Java variety, and the mono-cropping system.

The analysis reveals that the sum of the partial output elasticities with respect to all inputs is 1.25. This result indicates an increasing return to scale in coffee production. The implication of such a result is that a proportional increase in all the factors of production leads to a more than proportional increase in output. The result further reveals that coffee farmers can benefit from economies of scale linked to increasing returns to boost production.

The mean technical efficiency index is estimated at 0.896, and 32% of the farmers have technical efficiency indexes below 0.91. Furthermore, the estimated value of the variance parameter g for the stochastic frontier production function is not only close to one, but also significantly different from zero. These results show the existence of technical inefficiencies in arabica coffee production. On the average, coffee farmers can increase their output by 10% provided they operate along their efficient frontier. Consequently, if all farmers efficiently use the available resources, the resulting increase in output can partially offset the fall in product prices and thus improve the productivity of plantations and increase their income.

Furthermore, the result of the technical inefficiency effects model shows that the education level of the producer and access to credit are the major socioeconomic variables having a significant and negative influence on the farmers' technical inefficiency.

Two major policy implications may be highlighted:

1) Some productivity gains linked to improvements in technical efficiency can still be realized in the arabica coffee subsector in Cameroon. Moreover, producers can still take advantage of scale economies linked to increasing returns to increase output.
2) The variables indicating the producer's level of education and access to credit constitute instruments that can be manipulated within the framework of an agricultural policy in order to improve the technical efficiency of arabica coffee farmers. Actually, all policy measures that build the capacities of farmers will lead to a substantial reduction of technical inefficiency. The same thing obtains for those measures likely to facilitate farmers' access to credit.

As in the case of most empirical studies, the results obtained in this study should be considered as relative and not absolute in terms of magnitude. Moreover, the model used is limited in the sense that it does not consider other factors such as risks and market imperfections that can also influence the technical efficiency of farmers. Nevertheless, these limitations do not subtract from the validity of the study, since it has permitted us to not only estimate the technical efficiency indexes of coffee farmers in Cameroon for the first time, but also to identify the factors that affect their technical performance.

Notes

1. Between 2000 and 2005, the average annual growth rate of agricultural output is estimated at 4.1% (INS, 2005).
2. The US dollar is the currency of reference in trade between Cameroon and foreign countries.
3. The relative price of arabica coffee to robusta coffee is obtained by dividing the CIF price of arabica coffee by that of robusta.
4. Given that the dependent variable in the frontier is value of output rather than physical output, the inefficiency effects in the model may be influenced by allocative inefficiency issues. However, during the period of the study, agricultural policies essentially remained the same and it is expected that inefficiency effects in the frontier model are mostly associated with technical inefficiency in production.

References

Aigner, D.J., C.A.K. Lovell and P. Schmidt. 1977. "Formulation and estimation of stochastic frontier production function models". *Journal of Econometrics*, 6: 21–37.

Ajibefun, A.I., G.E. Battese and A.G. Daramola. 1996. "Investigation of factors influencing the technical efficiencies of smallholder croppers in Nigeria". Center for Efficiency and Productivity Analysis (CEPA) Working Paper No. 10/96. Department of Econometrics, University of New England, Armidale, Australia.

Ajibefun, A.I. and A.G. Daramola. 2004. *Efficiency of Microentreprises in the Nigerian Economy*, Research Paper No. 134. African Economic Research Consortium (AERC), Nairobi.

Ali, M. and J.C. Flinn. 1987. "Profit efficiency among Basmati rice producers in Pakistan Punjab". *American Journal of Agricultural Economics*, 71: 303–10.

Aragon, Y., A. Daouia and C. Thomas-Agnan. 2003. "Non parametric frontier estimation: A conditional quantile-based approach". Groupe de Recherche en Economie Mathématique et Quantitative (GREMAC) et Laboratoire des Statistiques et Probabilités (LSP), Université de Toulouse I http:/www.univ-tlse1.fr/GREMAC/Statistique. Accessed 22 October 2004.

Audibert, M. 1997. "Technical efficiency effects among paddy farmers in the villages of the Niger, Mali, West Africa". *Journal of Productivity Analysis*, 8: 379–94.

Bagi, F.S. 1987. "Relationship between farm size and technical efficiency in West Tennessee agriculture". *Southern Journal of Agricultural Economics*, 14: 139–44.

Battese, G.E. 1992. "Frontier production functions and technical efficiency: A survey of empirical applications in agricultural economics". *Agricultural Economics*, 7: 185–208.

Battese, G.E. and T.J. Coelli. 1995. "Model for technical inefficiency effects in a stochastic frontier production function for panel data". *Empirical Economics*, 20: 325–32.

Battese, G.E. and G.S. Corra. 1977. "Estimation of production frontier model: With application to pastoral zone of Eastern Australia". *Australian Journal of Agricultural Economics*, 21: 169–79.

Battese, G.E. and H. Sarfraz. 1998. "Technical efficiency of cotton farmers in Vehari District of Punjab, Pakistan". Center for Economic Policy Analysis Working Paper No. 8/98. Department of Econometrics, University of New England, Armidale, Australia.

Battese, G.E., T.J. Coelli and T.C. Colby 1988. "Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data". *Journal of Econometrics* ,38: 387–99.

Battese, G.E., T.J. Coelli and T.C. Colby. 1989. "Estimation of frontier production functions and the efficiencies of Indian farms using panel data from ICRISAT's village level studies". *Journal of Quantitative Economics*, 5: 327–48.

Belbase, K. and R. Grabowski. 1985. "Technical efficiency in Nepalese agriculture". *Journal of Development Areas*, 19(4): 515–25.

Ben-Belhassen, B. 2000. "Measurement and explanation of technical efficiency in Missouri hog production". Selected paper, American Agricultural Economics Association (AAEA), Annual Meeting. Tampa, Florida, 30 July – 2 August.

Bravo-Ureta, B.E. and A.E. Pinheiro 1997. "Technical, economic and allocative efficiency in peasant farming: Evidence from the Dominican Republic". *The Developing Economies,* XXX(1): 48–67.

Bravo-Ureta, B.E. and R.E. Evenson. 1994. "Efficiency in agricultural production: The case of peasant farmers in Eastern Paraguay". *Agricultural Economics*, 10: 27–37.

Cazals, C., J.P. Florens and L. Simar. 2002. "Nonparametric frontier estimation: A robust approach". *Journal of Econometrics*, 1: 1–25.

Charnes, A., W.W. Cooper and E. Rhodes. 1978. "Measuring the inefficiency of decision making unit". *European Journal of Operational Research*, 2: 429–44.

Cobb, C.W. and P.H. Douglas. 1928. "A theory of production". *American Econometric Review*, 18: 139–65.

Coelli, T.J. 1996. "A guide to FRONTIER version 4.1: A computer program for stochastic frontier production and cost function estimation". Center for Efficiency and Productivity Analysis (CEPA) Working Paper 96/07. University of New England, Armidale, Australia.

Coelli, T. and G. Battese. 1996. "Identification of factors which influence the technical inefficiency of Indian farmers". *Australian Journal of Agricultural Economics*, 40(2): 103–28.

Coelli, T., R. Prasada, and G. Battese. 1998. *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Press.

Dawson, P.J. and J. Lingard. 1989. "Measuring farm efficiency over time on Philippine rice farms". *Journal of Agricultural Economics*, 40: 168–77.

Debreu, G. 1951. "The coefficient of resource utilisation". *Econometrica*, 19: 273–92.

Deprins, D., L. Simar and H. Tulkens. 1984. "Measuring labor efficiency in post offices". In M. Marchand, P. Pestieau and H. Tulkens, eds., *The Performance of Public Enterprises: Concepts and Measurements*, pp. 243–67. Amsterdam: North-Holland.

Durasaimy, P. 1990. "Technical and allocative efficiency of education in agricultural production: A profit function approach". *Indian Economic Review*, XXV(1): 17–32.

Farrell, M.J. 1957. "Measurement of productive efficiency" *Journal of the Royal Statistical Society*, Series A, 120(3): 253–90.

Gilbert, C.L., E. Tollens, A. Nchare, F. Kamajou, A.S. Essomba, and H. Fankam. 1999. *Impacts of Economic Liberalisation in Cameroon's Coffee and Cocoa Sub-Sectors*. Final Report for the European Commission Delegation, Department of Finance, Faculteit der Economische Wetenschapeen, Vrije Universiteit, Amsterdam

Helfand, S.M. 2003. "Farm size and determinants of productive efficiency in the Brazilian Center-West". Paper presented at the 25th International Conference of the International Association of Agricultural Economist (IAAE). Durban, South Africa, 16–22 August.

Huang, C.J. and J.T. Liu. 1994. "Estimation of a non-neutral stochastic frontier production function". *Journal of Productivity Analysis*, 4: 171–80.

Hussain, S.S. 1989. "Analysis of economic efficiency in Northern Pakistan: Estimation, causes and policy implications". PhD dissertation, University of Illinois, Urbana-Champaign.

Institut National de la Statistique (2005), *Les comptes nationaux du Cameroun*. Yaoundé.

Jondrow, J., C.A.K. Lovell, I.S. Materov and P. Schmidt. 1982. "On estimation of technical inefficiency in the stochastic frontier production function model". *Journal of Econometrics*, 19: 233–38.

Kalirajan, K. 1981. "An econometric analysis of yield variability in paddy production". *Canadian Journal of Agricultural Economics*, 29: 283–94.

Kalirajan, K. and R.T. Shand. 1986. "Estimating location specific and farm specific technical efficiency: An analysis of Malaysian agriculture". *Journal of Economic Development*, 11: 147–60.

Kodde, D.A. and F.C. Palm. 1986. "Wald criteria for jointly testing equality and inequality restrictions". *Econometrica*, 54: 1243–8.

Koopmans, T.C. 1951. "An analysis of production as an efficient combination of activities". In T.C. Koopmans, ed., *Activity Analysis of Production and Allocation*. Cowles Commission for Research in Economics, Monograph No. 13. New York: Wiley.

Kouadio, Y. and K. Pokou. 1991. "Efficacité technique des petites et grandes exploitations dans le nord de la Côte d'Ivoire". Cahiers du CIRES 1: 7–23.

Kumbhakar, S.C., S. Ghosh and J.T. McGuckin. 1991. "A generalized production frontier approach for estimating determinants of inefficiency in U.S. dairy farms". *Journal of Business and Economic Statistics*, 9: 279–86.

Lyubov, A.K. and H.H. Jensen. 1998. "Technical efficiency of grain production in Ukraine". Paper presented at the 1998 American Agricultural Economics Association Annual Meeting, Salt Lake City, Utah, 2–5 August.

Meeusen, W. and J. Van den Broeck. 1977. "Efficiency estimation from Cobb–Douglas production function with composed error". *International Economic Review*, 18: 435–44.

Ministry of Agriculture. 2003. *Rural Sector Development Strategy Paper*.Yaoundé, Cameroon.

Nchare, A. 1999. *Comparative Advantage and Competitiveness of Cameroon's Coffees and Cocoa : An Analysis Using the Domestic Resources Costs Method*. Final Report for the European Commission Delegation, Vol. II, Vrije Universiteit, Amsterdam, November.

Nchare, A. 2002. "Impacts of economic liberalisation and of CFA franc devaluation on the arabica coffee and food crops supply in Cameroon". PhD dissertation, Department of Rural Economics, Faculty of Biological, Agronomic and Environmental Engineering, Catholic University of Louvain, Louvain-La-Neuve.

Nyemeck, J.B., Sylla, K. et Diarra, I. 2001. «Analyse des déterminants de la performance productive des producteurs de café dans une zone à faible revenu en Côte d'Ivoire». Final report , AERC, Nairobi.

Obwona, M. 2005. *Determinants of Technical Efficiency Differentials among Small- and Medium-Scale Farmers in Uganda: A Case of Tobacco Growers*. Research Paper No. 152. African Economic Research Consortium, Nairobi.

Owen, T., J. Hoddinott and B. Kinsey. 2001. "The impact of agricultural extension on farm production in resettlement areas in Zimbabwe". Working Paper CSAE WPS/2001-6. Centre for the Study of African Economies, University of Oxford.

Parikh, A., F. Ali and M.K. Shah. 1995. "Measurement of economic efficiency in Pakistani agriculture". *American Journal of Agricultural Economics*, 77: 675–85.

Pinheiro, A. 1992. "An econometric analysis of small farms in the Dominican Republic". MS thesis, University of Connecticut, Storrs.

Pitt, M.M. and L.F. Lee. 1981. "Measurement and sources of technical inefficiency in the Indonesian weaving industry". *Journal of Development Economics*, 9: 43–64.

Reifschneider, D. and R. Stevenson. 1991. "Systematic departures from the frontier: A framework for the analysis of firm inefficiency". *International Economic Review,* 32: 715–23.

ROC. 1996. *Lettre de Politique de Développement Agricole*, République du Cameroun, Yaoundé.

Rourke, B.F. 1970. "Short range forecasting of coffee production". Food Research Institute of *Agricultural Economics*, 9: 179–214.

Seyoum, E.T., G.E. Battese and E.M. Fleming. 1998. "Technical efficiency and productivity of maize producers in Eastern Ethiopia: A study of farmers within and outside the Sasakawa Global 2000 Project". *Agricultural Economics*, 19: 341–48.

Simar, L. and P. Wilson. 2000. "Statistical inference in nonparametric frontier models: The state of the art". *Journal of Productivity Analysis*, 13: 49–78.

Simar, L. 2003. *How to Improve the Performances of DEA/FDH Estimators in the Presence of Noise*. Discussion paper No. 0323. Institut de Statistique, UCL, Louvain-La-Neuve, Belgium. http:/www.stat.ucl.ac.be. Accessed 22 October 2004.

Snedecor, G.W. and W.G. Cochrane 1980. *Statistical Methods*. 7th edition. Ames, Iowa: Iowa State University Press.

Squires, D. and S. Tabor. 1991. "Technical efficiency and future production gains in Indonesia agriculture". *The Developing Economies*, 70: 338–46.

Weir, S. 1999. "The effects of education on farmer productivity in rural Ethiopia". Working Paper CSAE WPS99-7. Centre for the Study of African Economies, University of Oxford.

Weir, S. and J. Knight. 2000. "Education externalities in rural Ethiopia: Evidence from average and stochastic frontier production functions". Working Paper CSAE WPS2000-4. Centre for the Study of African Economies, University of Oxford.

Appendix – Supplementary data

Table A1: Evolution of the relative price of arabica to robusta coffee

Fiscal year	Arabica coffee		Robusta coffee		Relative price of arabica to robusta coffee
	CIF price (a)	Producer price	CIF price (b)	Producer price	(a/b)
1974	349	140	289	135	1.20
1975	309	150	672	145	0.46
1976	752	180	1,212	195	0.62
1977	1,271	275	734	250	1.73
1978	810	300	776	280	1.04
1979	814	330	685	310	1.19
1980	718	340	616	320	1.17
1981	767	350	805	330	0.95
1982	1,014	370	1,043	350	0.97
1983	1,106	410	1,331	390	0.83
1984	1,389	450	1,201	430	1.16
1985	1,442	475	1,129	440	1.28
1986	1,471	475	678	440	2.17
1987	744	475	625	440	1.19
1988	887	475	532	440	1.67
1989	752	250	330	175	2.28
1990	535	250	310	155	1.73
1991	528	250	355	155	1.49
1992	1,056	200	605	100	1.75
1993	1,017	200	1,350	270	0.75
1994	1,844	1,100	1,463	700	1.26
1995	1,200	600	813	500	1.48
1996	1,774	680	848	400	2.09
1997	1,719	1,100	963	550	1.79
1998	1,244	700	972	560	1.28

Notes: Prices are in CFAF per kilogram. CIF prices correspond to the arabica coffee price on the New York futures market and to the price of robusta coffee on the London futures market.

Sources: ONCC, CICC; calculation by the author.

Table A2: Technical efficiencies of sample coffee producers

Producer number	Technical efficiency	Producer number	Technical efficiency	Producer number	Technical Technical	Producer efficiency	Producer efficiency
1	0.841	36	0.867	71	0.922	106	0.860
2	0.961	37	0.983	72	0.966	107	0.983
3	0.977	38	0.977	73	0.944	108	0.915
4	0.914	39	0.927	74	0.907	109	0.807
5	0.961	40	0.940	75	0.964	110	0.911
6	0.984	41	0.974	76	0.618	111	0.793
7	0.967	42	0.970	77	0.963	112	0.945
8	0.969	43	0.729	78	0.683	113	0.583
9	0.521	44	0.955	79	0.970	114	0.979
10	0.810	45	0.956	80	0.788	115	0.973
11	0.962	46	0.954	81	0.982	116	0.914
12	0.923	47	0.958	82	0.759	117	0.983
13	0.809	48	0.750	83	0.757	118	0.957
14	0.981	49	0.966	84	0.779	119	0.701
15	0.974	50	0.672	85	0.655	120	0.973
16	0.958	51	0.970	86	0.980	121	0.962
17	0.968	52	0.969	87	0.960	122	0.961
18	0.965	53	0.979	88	0.744	123	0.963
19	0.963	54	0.937	89	0.765	124	0.975
20	0.911	55	0.774	90	0.634	125	0.908
21	0.971	56	0.968	91	0.970	126	0.985
22	0.926	57	0.942	92	0.984	127	0.744
23	0.942	58	0.967	93	0.931	128	0.976
24	0.985	59	0.898	94	0.964	129	0.854
25	0.817	60	0.965	95	0.812	130	0.973
26	0.959	61	0.978	96	0.926	131	0.939
27	0.985	62	0.914	97	0.917	132	0.822
28	0.885	63	0.959	98	0.963	133	0.984
29	0.971	64	0.984	99	0.777	134	0.982
30	0.963	65	0.781	100	0.857	135	0.966
31	0.852	66	0.970	101	0.770	136	0.926
32	0.980	67	0.950	102	0.956	137	0.968
33	0.936	68	0.967	103	0.246	138	0.950
34	0.951	69	0.917	104	0.970	139	0.972
35	0.771	70	0.985	105	0.478	140	0.654
Mean technical efficiency =0.896							

Sources: Study results.

Table A3: Estimated parameters of the translogarithmic stochastic frontier production function

Variable	Parameter estimate	Coefficient error	Standard	t-ratio
Constant	$\hat{a}_0$	7.800**	2.005	3.891
Ln (Land)	$\hat{a}_1$	6.685**	3.212	2.081
Ln (Labour)	$\hat{a}_2$	3.326	3.102	1.072
Ln (Fertilizer)	$\hat{a}_3$	- -6.410**	2.526	-2.538
Ln (Pesticides)	$\hat{a}_4$	0.967	2.166	0.446
Ln (Age of coffee tree)	$\hat{a}_5$	- -1.493**	0.500	-2.988
Ln (Capital)	$\hat{a}_6$	-8.741	1.978	-4.418
[Ln (Land)]^2	$\hat{a}_{11}$	0.218	0.185	1.178
[Ln (Labour)]^2	$\hat{a}_{22}$	-0.182	0.110	-1.659
[Ln (Fertilizer)]^2	$\hat{a}_{33}$	-0.050	0.081	-0.616
[Ln (Pesticides)]^2	$\hat{a}_{44}$	- -0.148**	0.059	-2.511
[Ln (Age of coffee tree)]^2	$\hat{a}_{55}$	0.288	0.363	0.795
[Ln (Capital)]^2	$\hat{a}_{66}$	0.115	0.060	1.927
Ln (Land) x Ln (Labour)	$\hat{a}_{12}$	0.126	0.221	0.568
Ln (Land) x Ln (Fertilizer)	$\hat{a}_{13}$	- -0.833**	0.223	-3.732
Ln (Land) x Ln (Pesticides)	$\hat{a}_{14}$	- 0.815**	0.242	3.368
Ln (Land) x Ln (Age of coffee tree)	$\hat{a}_{15}$	- -1.352**	0.422	-3.207
Ln (Land) x Ln (Capital)	$\hat{a}_{16}$	- -0.647**	0.163	-3.965
Ln (Labour) x Ln (Fertilizer)	$\hat{a}_{23}$	0.004	0.180	0.022
Ln (Labour) x Ln (Pesticides)	$\hat{a}_{24}$	-0.014	0.201	-0.068
Ln (Labour) x Ln (Age of coffee tree)	$\hat{a}_{25}$	-0.720	0.505	-1.426
Ln (Labour) x Ln (Capital)	$\hat{a}_{26}$	0.121	0.127	0.948
Ln (Fertilizer) x Ln (pesticides)	$\hat{a}_{34}$	0.130	0.139	0.941
Ln (Fertilizer) x Ln (Age of coffee tree)	$\hat{a}_{35}$	- 0.991**	0.378	2.618
Ln (Fertilizer) x Ln (Capital)	$\hat{a}_{36}$	- 0.322**	0.116	2.778
Ln (Pesticides) x Ln (Age of coffee tree)	$\hat{a}_{45}$	0.111	0.322	0.347
Ln (Pesticides) x Ln (Capital)	$\hat{a}_{46}$	0.083	0.109	0.762
Ln (Age of coffee tree) x Ln (Capital)	$\hat{a}_{56}$	- 1.168**	0.265	4.411
Total variance	σ_s^2	0.026	0.009	2.799
Variance ratio	γ	0.933	0.035	26.744
Ln (Likelihood)		161.464		

**Significant at 5% level.
Source: Study results.

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