Determinants of Technical Efficiency among Smallholder Coffee Farmers in Kigoma Region, Tanzania

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Abstract

Coffee is one of the most important export commodities in Kigoma region. Unfortunately, production is still low and information on technical efficiency has remained is scarce. This study sets out to contribute towards efforts for improving coffee productivity to enhance the cash income of smallholder Arabica coffee farmers in Kigoma region, Tanzania. The present study estimated the Technical Efficiency (TE) and inefficiency effects of inputs. The paper uses data collected from a sample of 122 farmers. Parameters of the generalized Cobb-Douglas stochastic frontier model for the production system were estimated by a single stage Maximum Likelihood (ML) method for the technical efficiency and technical inefficiency effects using the Frontier version 4.1 c, a computer program for Stochastic Frontier Production. The results show that inorganic fertilizers, agrochemicals and labour are key inputs. The mean Technical Efficiency index is 68%, indicating that farmers are technically inefficient, with a 32% scope for increasing Technical Efficient (TE).The number of coffee trees and a farmer's experience are the main determinants of TE. The study recommends farmers to increase application of productivity enhancing inputs. Moreover, there should be deliberate intervention on farm expansion, and training to engage youths in coffee production since they tend to be more technically efficient thereby improving the production system's TE.

Key words: *Technical Efficiency, Inefficiency Effects, Kigoma*

Introduction

Coffee is a major source of income for millions of smallholder farmers worldwide and it is a significant source of export earnings to many nations including Tanzania. Coffee is one of Tanzania's primary export crops representing about 5% of total export, 24% of traditional crops and generating export earnings which have averaged about US$ 100 million per annum over the last 30 years (TCB, 2011). The coffee industry provides direct income to more than 400,000 farm families and also benefits indirectly the livelihoods of 2.4 million Tanzanians. Arabica coffee covers about 80% of approximately 200,000 ha of the land under coffee production and represents about 70% of the output (URT, 2008). The Arabica coffee growing regions are Arusha, Kilimanjaro, Mbeya and Ruvuma,Kigoma, Iringa, Tanga, Morogoro, Manyara, Rukwa, Mwanza and Mara. Robusta coffee is only produced in Kagera region (TCB, 2011).

Coffee is the main cash earning agricultural commodity in Kigoma region, but, yield per hectare is still low. According to TCB (2011), the yield of Arabica coffee in Tanzania is estimated to be 200-300 kg/ha while that of Robusta coffee is 750 kg/ha. Another study (URT, 2011) reports that the average Arabica coffee yield is 151kg/ha, which is lower than the national yield average ranging between 200 and 250kg/ha. Tanzania Coffee Research Institute (TaCRI) (2009) contends that inefficient use of inputs such as inorganic fertilizers, shortage of improved coffee varieties, prevalence of pests and diseases, insufficient support from extension services significantly contribute to low coffee productivity in Tanzania.

Globally, there is disagreement on whether large scale coffee production is more efficient than small scale production. There is no clear evidence whether large farms are more productive and more efficient than small farms (Lerman and Sutton, 2006). According to Jeffrey (1992), small scale farmers are less efficient because they often face more difficulty in accessing credit, which may also inhibit their ability to adopt relevant improved technologies.

Consistent with this argument, a study by Ayoola (2012) on economic analysis of coffee production in Nigeria found that, large-scale farmers were more technically efficient than small-scale farmers. He argued further that large scale

farming is a business oriented activity, whereas small farmers spend resources efficiently thereby reducing their profit levels. However, Cardenas (2005) who investigated the efficiency of coffee production in the state of Veracruz in Mexico found that smallholder coffee farmers were more technically efficient than large coffee estates. The current research set out to determine to technical efficiency of small scale coffee farmers in Kigoma Tanzania relative to other studies, which have been done before elsewhere in the country to assess the efficiency of coffee farmers.

According to Shujie and Chunxia (2007), TE and its determinants can be estimated using either a single stage approach or a two-stage approach. In the single-stage approach; the potential relationship between the firm specific variables and technical efficiency is imposed in a single-stage procedure to estimate the production technology and firm efficiencies (Kumbhakar *et al.*, 1991; Reifschneider and Stevenson, 1991; 1994; and Battese and Coelli, 1995). In the two stages process, the first stage measures the level of efficiency/inefficiency using a normal production function. The second stage, determines socio-economic characteristics that influence the level of technical efficiency, using a Probit model where TE is the dependent variable and socio-economic characteristics are independent variables. The Monte Carlo approach, which is used in the two stages to assess TE is known to suffer from bias since it exaggerates the efficiency scores while underestimating the frontier values due to assumptions regarding the independence of the inefficiency effects (Kumbhakar and Lovell, 2000). To rectify such problems and bias, the single stage approach is applied whereby the stochastic frontier and inefficiency models are jointly estimated.

In Tanzania, there are limited published research works which have applied the single stage stochastic frontier analysis model in determining farmers' technical efficiency and its determinants. Available publications applied the two stage stochastic frontier approach (Asmerom *et al.*, 2015; Mkondya, 2009; Srinivasulu *et al.* ,2014; Michael, 2013; Mwajombe and Mlozi, 2015). Research work analyzing coffee production efficiency include Mkondya (2009) and Mwakalobo (1997) in Mbozi and Rungwe district respectively. The two studies established that smallholder coffee farmer in Mbozi district were on average 82% technically efficient while farmers in Rungwe district were on

average 49.2% technically efficient. However, little is known about the technical efficiency and its determinants among smallholder coffee farmers in Kigoma region. According to URT (2011), coffee production in Kigoma is at a nascent stage in coffee production, involving about 4,000 households.

Mkondya (2009) asserts that allocation of production resources is determined by the given set of ecological, social, managerial and technological option(s) at a particular point of time. Hence research findings from Mbozi, Rungwe, Kilimanjaro and elsewhere can not necessarily be generalized to other places such as Kigoma, due to problem of external validity. This, study on the TE of coffee farming in Kigoma contributes to the stock of knowledge on TE in Tanzania. The study also contributes to the scientific debate on whether large scale coffee farming is more efficient than small scale for the same crop. Moreover, the knowledge generated provides insights to farmers and other stakeholders of the coffee sub-sector to make informed decisions for improving coffee production and marketing.

Literature Review

The Coffee Industry Development Strategy (CIDS) 2011/2021 for Tanzania, states her mission to increase coffee production from the present average of 50,000 tons to at least 80,000 tons by the year 2016 through planting about 10,000 hectares. While this strategy foresees positive change, the Northern part of Tanzania which used to be the home of coffee; by 2013, when this study was done, farmers had abandoned the crop (and the trend continues), shifting resources to other crops such as maize, bananas, rice, vegetables and dairy farming (Ikeno, 2007). According to Ikeno (2007), in 2000/01 only 12% of households in Kilimanjaro Region reported to depend on coffee as their main source of income compared to 56% in Ruvuma Region. Makoye (2015) similarly shows that farmers in the Northern coffee producing zone in Tanzania have been abandoning coffee farms because coffee production is no longer profitable compared to other crops and dairy farming. Currently, coffee is mainly produced in the Southern Highlands (Mbinga and Mbozi). Increased production in the Southern Highlands has offset the decline in the Northern Highlands, such that Tanzania's average coffee production has not shown a dramatic drop since the late 1980s (TCB, Ikeno, 2007). Figure 1 shows the evolution of coffee production in Tanzania, whereby in 1980s, the Northern

zone used to contribute about 66% total coffee produced. However by 2008 its contribution declined to only 28%.

Figure 1: Evolution of the contribution from each production area to total Tanzania Arabica exports (1980-2008).

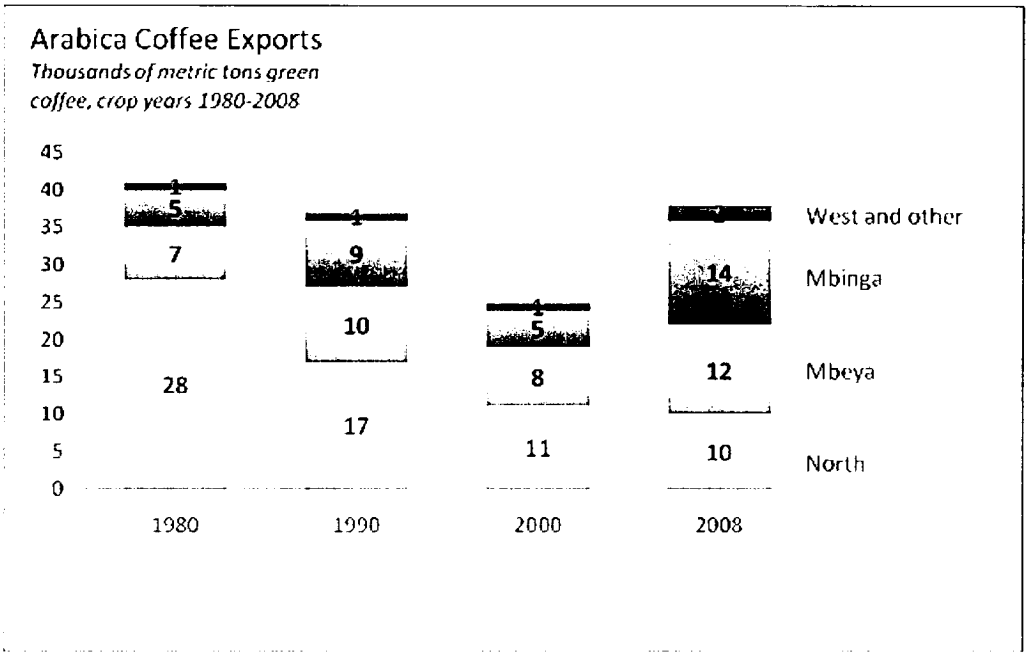

Figure 1: Contribution from each production area to total Tanzania Arabica exports (1980-2008).

Source: TCB, 2012

The observed shift by farmers is a reflection of their assessment regarding the relative returns from alternative investments. It has been argued that farmers are rational economic agents Ikeno (2007). They compare the cost and benefit at the margin and choose the best option. Recognized the declining trend of the coffee economy, the government of Tanzania responded by introducing a coffee diversification programme was introduced with support from the International Coffee Agreement (ICA) in order to support the introduction of new crops on land where coffee previously grew (Smith 1980; cited by Ikeno 2007). The diversification programme accelerated the farmers' decision to abandon coffee farms. Given the new alternative, Ikeno (2007) argues that coffee growers had several options which include: (i) no strategy (wait for

producer prices to recover), (ii) develop strategies within the coffee subsector, such as expanding the area under coffee production or improving the quality of coffee sold, targeting specialty markets such as selling organic under the Fairtrade label, (iii) develop a strategy within the agricultural sector such as changing the cropping pattern or shifting to dairy farming, and (iv) develop a strategy in another sector such as engaging in nonfarm activities within villages and/or in nearby towns.

Many farmers in Northern Tanzania opted for the fourth strategy, which entailed changing their cropping pattern or shifting to dairy farming and non-farm activities. However, in the Southern Highlands farmers opted for farm expansion. In remote regions such as Kigoma, where coffee production remains an important option for earning cash income, farmers are likely to expand coffee production because land is still available for expansion. However, focusing on productivity improvement is equally important. Understanding factors that enhance or impeding future development of the coffee sub-sector in Kigoma region is therefore very pertinent.

Such factors may vary from one place to another. Research findings by Salazar (2006) on the use of organic fertilizers in coffee production in Guatemala, Honduras, Nicaragua and Vietnam found that, in these countries, organic fertilizer had almost no impact on coffee yield while in Vietnam organic fertilizer had a positive correlation with coffee yield. Another study by the African Economic Research Consortium (AERC) (2007) on factors affecting the technical efficiency of Arabica coffee producers in Cameroon found that efficiency was a decreasing function of the farmers' education level and the number of hours of instruction received by those farmers who participated in programmes provided by extension services. However, for farmers who were still using traditional production methods, their level of education did not significantly affect technical the efficiency of coffee production. Such insights make it plausible to undertake a location specific study in Kigoma region focusing on coffee production.

Methodology

This paper uses data collected from Kigoma region in 2013. Kigoma region is located between latitudes 3.6 and 6.5 degrees South and longitudes 29.5 and

31.5 degrees East. To the North the Region borders Burundi and Kagera Region; it borders Shinyanga and Tabora to the East, Rukwa Region to the South and the Democratic Republic of Congo to the West (URT, 2008). Coffee growing in Kigoma Region is concentrated in the wetter areas of the highland zone along Lake Tanganyika in the Northern part of the Region. Coffee production is concentrated in Manyovu and Kalinzi divisions within Buhigwe and Kigoma districts respectively. Altitude in the Highland zone ranges between 1,500 and 1,700 meters above sea level while annual rainfall varies between 1,300mm and 1,650mm. Kigoma Region is divided into three agro-economic zones, the lake shore zone, the lowlands zone and the highlands zone. Arabica coffee is grown in parts of Kigoma, Buhigwe and Kibondo districts. However, within each district some wards do not grow coffee.

Using a cross sectional design, multi stage sampling was employed to select districts, villages and households. The first stage involved purposive selection of Buhigwe and Kigoma districts where coffee is produced. Then two leading coffee producing divisions, one from each district were purposively selected. In the next stage three wards were selected randomly from among coffee producing wards: one from Buhigwe District and two from Kigoma District. The next stage involved random selection of six villages: two from each ward. The last stage involved proportional random selection of households from each village. A total of 122 households were selected for the sample. A structured questionnaire was used to collect data.

The efficiency of any firm can be measured directly using the Stochastic Frontier Analysis (SFA) or Data Envelopment Analysis (DEA). The SFA approach requires different functional forms for its application. It has been used to measure efficiency in different areas of agricultural economics (Greene, 2005; Bravo-Ureta and Pinheiro, 1993; Aigner *et al.*, 1977 and Meeusen and van den Broeck, 1977). The outputs of SFA are technical efficiency indices per farmer, coefficients of factor inputs and the coefficients of factors affecting inefficient. Meanwhile, DEA is a non-parametric approach that uses linear programming to construct a piecewise frontier (Charnes *et al.* (1978). According to Coelli *et al.* (2005) the key advantage of DEA over other approaches of measuring efficiency, is that it can easily accommodate multiple

inputs and outputs. Using DEA, there is no need to impose a specific functional form on the estimation model (Philip, 2007).

However, the SFA is superior to DEA because it can accommodate many variables such as weather, pests and diseases, which are characteristic of agricultural production functions. A stochastic production function is also able to account for measurement errors that could interfere in the process of shaping the frontier. Parameters of the generalized Cobb-Douglas production are estimated using a single stage Maximum Likelihood (ML) method for the technical efficiency and technical inefficiency effects in Stochastic Frontier Analysis.

However, if an explicit distribution is assumed, such as exponential, half-normal or gamma distribution, then the frontier is estimated by the Maximum Likelihood Estimates (MLE) method. According to Greene (2002), MLE makes uses the specific distribution of the disturbance term, which is more efficient than corrected ordinary least squares (COLS). Greene (2002) and Wooldridge (2002), independently explain that ML estimation is the unifying theme and the most efficient estimation procedure in the class of estimators that use information on the distribution of the endogenous variables given the exogenous variables. Aigner *et al.* (1977) parameterized the log-likelihood function for the half-normal model in terms of $\sigma^2 = \sigma_v^2 + \sigma_{z\delta}^2$and $\gamma^2 = \sigma_{z\delta}^2/\sigma_v^2 \geq 0$whereby if $\gamma = 0$ there are no technical inefficiency effects and all deviations or inefficiencies from the frontier are due to noise. Using this parameterization, the log-likelihood function is given by:

$$\ln L(y|\beta, \sigma, \lambda = -1/2 \ln(\pi\sigma^2/2) + \sum_{i=1}^{1} \ln\Phi(-\varepsilon_i\lambda/\sigma) - 12\sigma^2 \sum_{i=1}^{1} \varepsilon_1^2 \quad \ldots\ldots\ldots(1)$$

Where: y is a vector of log-outputs (kg), $\varepsilon_1 \equiv v_i - z_i\delta_i = \ln q_i - x_i'\beta$is a composite error term and $\Phi(.)$ is the cumulative distribution function (cdf) of the standard normal variable evaluated at x. The generalized likelihood ratio is therefore given by:

$$\lambda = -2\ln[L(H_0)/L(H_1)] = -2[L(H_O) - L(H_1)] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:$L(H_0)$ and $L(H_1)$ are values of the likelihood function under specification of the null (H_0) and alternative (H_1)hypotheses.The Cobb-Douglass production frontier is given by:

$$Y_i = f(x_i\beta_i)\exp(v_i - z_i\delta_i - w_i) \quad (3)$$

$$Y_i = \beta_o \sum_{n=1}^{N} x_n^{\beta_o} \exp(v_i - z_i\delta_i - w_i) \quad (4)$$

$$\ln Y_i = A + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + v_i - (\delta_1 z_1 + \delta_2 z_2 + \delta_3 z_3 + \delta_4 z_4 + \delta_5 z_5 + \delta_6 z_6 + w_i) \quad (5)$$

$$\ln Y_i = A + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + v_i - \delta_1 z_1 - \delta_2 z_2 - \delta_3 z_3 - \delta_4 z_4 - \delta_5 z_5 - \delta_6 z_6 - w_i \quad (6)$$

The technical efficiency for the i^{th} firm is defined by equation 7 while the technical inefficiency effects model is defined by equation 8.

$$TE_i = \exp(-z_i\delta_i - w_i) \quad (7)$$

Where $z_i\delta_i$ is defined as;

$$\delta_i z_i = \delta_o + \delta_1 z_1 + \delta_2 z_2 + \delta_3 z_3 + \delta_4 z_4 + \delta_5 z_5 + \delta_6 z_6 + \delta_7 z_7 + w_i \quad (8)$$

All the variables from equation 3 to 8 are defined as follows;

Yi	Cherry coffee yield expressed in kg/tree
ln	Natural logarithms
A	Constant
β_i and δ_i	Unknown parameters under estimation
v_i	Random error
w_i	TE effects which are not iid$N^+(0, \sigma^2_{z\delta})$
X_1	Quantity of inorganic fertilizers expressed in kg
X_2	Value of agrochemicals used expressed in TZS
X_3	Amount of labour expressed in man days
X_4	Organic fertilizer used expressed in 10kg bucket
X_5	Age of coffee tree expressed in years
Z_1	Experience of the farmer expressed in years
Z_2	Education level
Z_3	Household size expressed in number of individuals in the household
Z_4	Dummy variable on belonging to farm cooperative
Z_5	Dummy variable on farm mulching
Z_6	Number of coffee trees

Results and Discussions

Input productivity and technical efficiency estimates

The Maximum Likelihood (ML) estimates for the parameters of the stochastic frontier and the inefficiency models are shown in Table 1. The estimated Log likelihood function is (122.2)[1] and is statistically significant at 5% level. The variance parameter (σ^2) is 0.50 and is statistically significant at the 5% level of significance. These indicate a good fit and correctness of the distributional form assumed for the composite error term. The average technical efficiency (TE) (Table 2) is 68% implying the technical inefficiency among producers at about 32%[2]. The value of γ is 0.255 (Table 2), implying that technical inefficiency due to managerial decisions represents about 25% of all the inefficiency, hence accounting for 8% out of the total inefficiency, which is 32%. The remaining 24% is due to exogenous variables such as weather, pests and diseases.

A basic summary of the values of the key variables used in the stochastic frontier production function (Table 1) indicates that all input factors had positive coefficients and four of them were statistically significant, implying that an increase in use of these variables would lead to significant increase in output and TE. The coefficient for inorganic fertilizers (0.0848) is positive and statistically significant at 5%, implying that increasing the level of inorganic fertilizers by 1% would increase coffee output per tree. This demonstrates the importance of this input, which enhances the effect of other soil fertility enhancing inputs. The estimated coefficient for agrochemicals (0.0758) is positive and statistically significant at 1%, implying that increase in agrochemical application *ceteris paribus* leads to an increase in coffee output.

It is important to note that application of agrochemicals is determined by, among other things, the prevalence of diseases and pests. If the field is free from diseases and pests; one cannot explain the role of agrochemicals in increasing productivity and TE among coffee farmers in Kigoma region. Furthermore, the world coffee market is increasingly concerned about chemical residues found in coffee beans, which affect human health. According to

[1]The critical value of the test statistic is 15. It is obtained from Kodde and Palm 1986: 1246, Table with degree of freedom 8.

[2] Technical inefficiency = 100-TE; (100-68) =32; 32*γ =32*0.25 =8

TaCRI (2007), coffee exported from Tanzania were below standard due to high chemical residue levels. Hence, to address this challenge, farmers should be provided with disease resistant coffee varieties in order to reduce agrochemicals use while maintaining a high quality of coffee beans at a lower production cost.

The coefficient of age of coffee tree is 0.2854 and significant at 10% level. This implies that increase in age of coffee tree will *ceteris paribus* lead to an increase in coffee output. These results can be attributed to the fact that older trees have large branches which increases the number of coffee beans per tree. According to Parikh (1979) cited by Salazar (2006), a coffee tree reaches its optimum level of production between 9 and 20 years, declining thereafter until the age of 30 years.

Table 1: Estimates of the stochastic frontier for coffee producers in Kigoma region: 2012/2013 season

Variable names	Coefficient	Standard-error	Z-ratio	Expected sign
Constant β_0	1.5902*	0.8237	1.9306	+
Inorganic fertilizers (β_1)	0.0848**	0.3502	2.4212	+
Value of agrochemicals (β_2)	0.0758***	0.0204	3.7141	+
Labour (β_3)	0.8361***	0.1240	6.7440	+
Organic fertilizers (β_4)	0.0138	0.0100	1.3720	+
Age of coffee trees (β_5)	0.2854*	0.1662	1.7173	+/-
Inefficiency variables				
Constant δ_0	0.6734	0.7236	0.9306	+
Experience of a farmer (δ_1)	-0.1297*	0.0689	-1.8811	-
Education level (δ_2)	-0.4614	0.3412	-	-
Household size (δ_3)	0.0203	0.0603	0.3377	+
Dummy for cooperative membership (δ_4)	0.6736	0.2469	0.2728	-
Dummy for farm mulching (δ_5)	0.1906	0.2506	0.7606	-
Number of coffee trees (δ_6)	-0.0021***	0.0007	-2.8034	-
Dependent variables equation: Y = Cherry coffee output Tree				
σ^2	0.5017***	0.0674	8.5149	
γ	0.255***	0.1266	2.0095	
Log likelihood function		-0.1223**		
Likelihood Ratio (LR) test	14.2037**			

*, ** and *** Significant at 10%, 5% and 1% level respectively

However, with systematic stumping, coffee tree can continue to produce highly up to a maximum of 25 years and declines thereafter until the age of 40 years. The significances of age of coffee trees in relationship to output is consistent with results obtained by Salazar (2006) in their economic analysis of smallholder coffee production in Guatemala, Honduras, Nicaragua and Vietnam.

Distribution of Technical Efficiency (TE)

The findings in Table 2 show that the mean TE indices for Kigoma and Buhigwe districts are 69% and 65% respectively. The overall mean TE for the entire sample was 68%, which implies that production per coffee tree was on average about 32% below the potential due to the specific inefficiencies pertaining to farms. Given the range of technical efficiency levels, it means that if the average farmer in the study area was to achieve the TE level of the most efficient farmer, then the average farmer could realize 29%[3] input savings. Also the most technically inefficient farmer could achieve input saving of 74%[4]. In addition, the technical efficiency variations and mean technical efficiency obtained in this study are in line with results by Joachim *et al.* (2005) on sources of technical efficiency among smallholder maize and peanut farmers in Cameroon.

Table 2: Summary statistics of efficiency for 2012/2013 season

Statistics	TE score (%)		p=0.167
	Kigoma (n=83)	Buhigwe (n=39)	Pooled Sample(n=122)
Mean	69	65	68
Standard Deviation	14	16	14
Minimum	35	25	25
Maximum	96	88	96
TE Distribution			
Below 25	0	2	2
25-45	5	11	7
46-68	41	39	40
69-85	42	40	41
Above 85	12	8	10

[3][(1-(68.96))*100%]

[4][(1-(25.96))*100%]

Results in Table 2 also show the distribution of TE by district and the overall distribution, whereby about 2% of farmers were operating below 25% TE, while about 7% of the farmers were operating between 25% and 45% level of efficiency. Only 40% farmers achieved between 46-68% of efficiency. The results further indicate that about 41% of farmers were operating between 69% and 85% level of efficiency while about 10% achieved above 85% level of efficiency. The distribution of statistics in Table 2 follow a similar distribution revealed by Ayola (2012) on economic analysis of coffee production among large scale farmers in Nigeria. Result by Enwerem and Ohajianya (2013) similarly indicate that the mean TE index of large scale farmers was 65%; 3% below mean TE obtained by this study result, which implies that both large and small scale farmers may have comparable TE index; hence, suggesting scope for improvement by reallocating existing resources more optimally under both production scales.

Determinants of Technical Efficiency

As reported earlier, about 32% of coffee is lost because of technical inefficiency. The farmers' managerial decisions on production contribute about 25% (γ=0.25) to total yield losses. The results in Table 1 show that coefficients for household size, mulching and membership in cooperative societies have positive sign but they are not statistically significant at 5% level. Education level has a negative sign, which implies that educated farmers are less technically inefficient.

The inefficiency model shows further that the coefficient for experience in coffee farming is negative (-0.1297) and statistically significant at 10%, implying that experienced farmers are more efficient than new entrants. According to URT (2016), one of the strategies for development is to have experienced farmers to invest more in coffee production by facilitating youth to be involved in agriculture. This provides an opportunity for increased economic development in the entire area which would contribute significantly to reducing unemployment and hence, contributing to poverty reduction. This finding is in line with results obtained by Muhammad-Lawal *et al.* (2009) from their study on technical efficiency of youth participation in agriculture in the Youth-in-Agriculture Programme in Ondo state, South Western Nigeria where they found that early involvement in agriculture improves technical efficiency.

The coefficient for the number of coffee trees is also negative (-0.0021) but statistically insignificant at 5%. This implies that farmers having a large number of coffee trees are likely to be more efficient than farmers who have few trees. This arises because farmers with a large number of trees spend much of their time working in coffee farm; they also allocate much of their resources to coffee production compared to those farmers having a few trees, hence achieving higher TE. These results are consistent with similar findings by Over field and Fleming (1999) from their study on the technical efficiency of smallholder coffee producers in Papua New Guinea. They explained that the higher the proportion of the total income contributed by coffee output and the more integrated into the cash economy, the more likely it is that producers will **strive** to achieve higher technical efficiency in production. The reverse is true for farmers who have fewer trees.

Hypotheses Testing

The study set out to test three hypotheses. The first null hypothesis states that smallholder coffee farmers in Kigoma region are technically efficient($H_o: \lambda = z_i\delta_i = 0$). The computed test statistic ($\lambda = 14.204$) in Table 1 is greater than the critical value $\chi^2_{0.05}(2.7060)$[5] from the χ^2Table. Hence the null hypothesis is rejected and the conclusion is made that smallholder coffee farmers are technically inefficient due to reasons already alluded to above.

The second null hypothesis states that socio-economic factors do not significantly influence the farmers' technical inefficiency ($H_o: \gamma = 0$). Results of testing the hypothesis for the presence of inefficiency effects show that the computed Z-ratio value is 2.0095 while the tabulated value (p=0.05) is 1.96. Hence the null hypothesis is rejected, which makes it plausible to conclude that the joint effects of socio-economic variables contribute significantly to account for coffee production inefficiency.

The last hypothesis states that individual variables included in the inefficiency effects model have no effect on the level of technical inefficiency ($H_o: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$). The results in Table 1 indicate that the

[5] The critical value of the test statistic is obtained from Kodde and Palm (1986: 1246, Table 1) at the 5% level of significance with degree of freedom 1.

computed Z-value for farming experience is significant at p 0.1 while for the number of coffee trees is significant at p 0.05. The education level is negative but not significant while household size, cooperative membership and farm mulching variables are positive but not significant. Overall the null hypothesis is rejected because some coefficients are significantly greater than zero, enhance it is plausible to conclude that socio-economic characteristics of smallholder coffee farmers influence their technical efficiency.

Conclusions

These results show that smallholder coffee farmers in Kigoma region, specifically in Kigoma and Buhigwe districts are technically inefficient, which means there is a scope for increasing coffee production resulting from increased technical efficiency. Furthermore, the results show that all inputs collectively contribute significantly and positively to account for variation in yield per coffee tree with the exception of organic fertilizer whose coefficient was not significantly not different from zero. This implies that farmers were applying inputs below the optimum level. Hence production can be increased by improving increasing the inputs use and subsequently technical efficiency. The farmers' experience and the number of coffee trees are very important in improving technical efficiency.

Recommendations

The findings of this study as presented above show a number of key findings. First, expansion of coffee farms is very important for technical efficiency improvement. The results show that increasing the number of coffee trees would significantly improve TE. This finding is consistent with the Tanzania Coffee Board interim plan to implement the Tanzania Coffee Industry Development Strategy 2011-2021 which aims at distributing 20 million seedlings to farmers by 2021.

Second, to have experienced farmers who can take lead in business oriented agriculture, efforts should be made to influence youth participation. Moreover, the youths should be assisted to have better access to the necessary inputs of production such as fertilizers, land and agrochemicals. To improve their skills and knowledge in coffee production, they should be assisted to acquire better and effective training through participation in training programmes and

workshops. Thus, high productivity and income will be gained through increased efficiency in using existing farm technologies.

Third, the study reveals that coffee production can be increased by 25 per cent without increasing the level of inputs, if this inefficiency is reduced to zero. In other words, coffee farmers can gain considerable higher profits just by increasing the efficiency in their operations. Farming experience is one of the critical factors for increased efficiency in input use. Efforts should be made to support experienced farmers who can take the lead in business oriented agriculture; efforts should be made to influence youth participation. Further experience is gained through training on good agricultural practices especially on proper input uses. It is also recommended that actors such non-governmental organizations should facilitate farmers to acquire knowledge on the appropriate use of inputs to enable them get the highest output feasible moving toward the production frontier.

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