Assessing Agricultural Productivity among Smallholder Coffee Farmers in Tanzania: Evidence from Rungwe District

A. B. S. Mwakalobo[18]

ABSTRACT

This paper presents empirical findings on resource productivity and allocation efficiency in smallholder coffee farmers in Rungwe district. The data used in this paper are based on a case study that involved interviewing 90 farmers. A Cobb-Douglas production function was used to estimate the production organization of the coffee farmers, and their efficiency in resource use. The results show that the farmers display a low level of efficiency in using available resources. The results indicate further that farmers would increase farm productivity by the using adequate capital-intensive input levels in order to maximize their efficiency. In order to achieve the use of capital-intensive inputs, farmers should take advantage of increasing their bargaining power in both input and output markets. Farmers' groups/associations further provide group liability in the procurement of credit from both formal and informal financial lending institutions. This in turn will improve farmers input purchasing power. The knowledge and skill on how to improve both the institutional and technical aspects of coffee production require regular updating so that farmers can optimize the use of available resources. Continuing education for farmers is therefore emphasized for promoting efficient resource utilization as well as enhancing farm productivity.

Key words: Resource productivity, allocation efficiency, smallholder coffee farmers,

Introduction

The period prior to Structural adjustment development policies in Tanzania[19] was characterized by the national economy and its agricultural sector being heavily controlled by the government. Price and Market interventions were important policy instruments during that period. The objectives of government interventions in agricultural marketing were to reduce price uncertainties to producers, and hence stabilize farm income, provide adequate food to the urban population at reasonable price and maintain political stability. Other objectives were to protect farmers from exploitation by private traders, extract agricultural surplus for the development of other sectors of the economy, guarantee foreign exchange earnings, and reduce

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[18] Lecturer, Development Studies Institute, Sokoine University of Agriculture, Tanzania.

[19] Structural adjustment policies in Tanzania were first introduced in 1981 when the government through its own initiatives launched the Structural Adjustment Programme (SAP). This was soon followed by the National Economic Survival Programme (NESP) in 1983. Both were not very successful but they initiated a process of economic transformation that was further consolidated under the World Bank/IMF funded Structural Adjustment Programme (SAP) in 1986 and other subsequent programmes.

income inequalities between rural and urban areas as well as between regions (Amani, 1992).

During the same period the government influenced the allocation of agricultural resources at smallholder level using official markets and official pan-territorial prices for producers and consumers. Other mechanisms of interventions that influenced farm resource allocation included technology support and input packages (Simon, 1998). There was as well an attempt by the state to either influence or change social relations within production systems and thereby mobilize production forces for its effective use. All these were done in order to improve production and productivity at the smallholder sub-sector (Amani, 1992), which is the most dominant, accounting for over 80% of the crops produced.

Other means by which the government influenced smallholder resource allocation include registration of minimum size of land under cash and drought resistant crops (such as Cassava and sorghum) and land use directives related to settlements. Farmers were also forced by the government to apply fertilizers for the crop production (Amani, 1992).

But, following the implementation of SAP policies, the government and its agencies have withdrawn from such direct influence in agricultural resource allocation both at the national level (in terms of supply and demand) an at the farm level, in terms of utilization levels. There is a large and growing body of literature which shows that removal of price controls and of the parastatal marketing monopolies has opened up economic opportunities for trade in agricultural products (see Mwakalobo, and Kashuliza, 1998, Mwakalobo, and Kashuliza, 2000). However, it has been also reported by many authors, that other market reforms have pushed up prices of farm inputs relative to outputs (Mwakalobo, 1998, Mwakalobo and Kashuliza, 1998; 2000; Turuka, 1995; Hawassi, 1997, Hammond, 1999), thus affecting ability of smallholder farmers to use productivity enhancing inputs.

Market reforms have been implemented in order to restore the basis for sustainable economic growth by providing increased incentives to agricultural producers. These policy changes have important implications for farmers, as they directly affect their welfare. How, farmers adapt to these changes, and how such changes ensure more efficient production of crop ultimately depends on the efficient use of production resources on the farm as well as the adoption of better strategies in resource use, which requires copping with the changes (Amara, *et al.*, 1999).

For this reason resource productivity, allocation efficiency, and sound strategic resource use practices are important factors in proposing useful or effective structural changes within the farm sector and in designing public policies that increase farmers' chance of using resources efficiently in both the medium and long runs. This paper presents empirical findings on resource productivity and allocation efficiency among smallholder coffee farmers in Rungwe district. Based on the findings, this paper proposes possible strategies and interventions that will help to promote and enhance smallholder coffee production in Rungwe district and elsewhere in the country with similar farming systems. The issue of providing continuing education to farmers is emphasized as an important strategy for promoting efficient resource use and enhancing productivity.

Methodology

The findings presented in this paper are based on the data that were collected from a field survey conducted during the months of March to April 1997. Primary data were collected from 90 farmers, randomly selected from six villages[20] in Ukwekwe and Pakati division in Rungwe district. A structured questionnaire was used to interview the farmers regarding their production process in coffee, particularly focusing on resource use. Additional information was also obtained from discussion with key informants (i.e. village leaders, village extension officers). Other farmers outside the formal sample also provided supplementary field data.

Analytical framework

The notion of efficiency is usually associated with production frontier. In this paper, a non-frontier technique is used to investigate efficiency using the major factors for production under smallholder agriculture in Tanzania (land, capital input and labour). The Cobb-Douglas production function, which is commonly used, falls under the category of non-frontier models that measure efficiency.

They are preferred, partly due to their convenience in estimation and simplicity in the interpretation of estimated coefficients. The estimated equation is an average function rather than a frontier function.

The variables used in the analysis were defined as follows:-

- Output is the gross value of total production of coffee during the 1996 crop season.
- Land is the total land in hectares under coffee cultivation during the survey.
- Capital is the value in Tshs of farm inputs (fertilizers, herbicides, and pesticides) used in coffee production.

The usual formulation of the Cobb-Douglas production function has the following general form:

$$Q_i = AX_i^{bi} e^u \quad \text{..} \quad (1)$$

Where, Q_i = total output of coffee of the i^{th} farm

A = constant term of the regression

[20] Three villages were selected from each division, (The three villages include; Kyimo, Mpandapanda, and Ibula from Ukukwe division and Segela, Katundulu and Mpuga from Pakati division)

b_i	=	elasticity of production with respect to the i^{th} input;
X_i	=	i^{th} input used in the production process
U	=	is the error term
e	=	the base of the natural logarithm

Specified in this form, the regression coefficients of the log transformation of the model represent the elasticities of production of the respective inputs. These elasticities are also independent of the unit of measurement. This model facilitates the estimation of the marginal resource productivity at the mean level and the computation of returns to scale. The empirically estimated Cobb-Douglas production function model in its log-linear form is specified as follows:

$$LnQ_i = LnA + b_1 LnX_1 + b_2 LnX_2 + b_3 LnX_3 + U \text{ ....} \quad (2)$$

Where,

Ln	=	the natural logarithm
LnX_1	=	area under coffee
LnX_2	=	labor employed in the production process
LnX_3	=	Value of capital inputs (Tshs) per farm. The capital inputs include fertilizer, pesticides and herbicides

Estimation of this model was done using the Statistical package for Social Scientists (SSPS). Assuming that errors are normally distributed the equation can be estimated using ordinary least squares method. Analysis was also done to determine the overall technical efficiency of coffee production of farmers in Rungwe district.

The estimated Cobb-Douglous production function was used to derive marginal productivity (MP) estimates. When the MP is transformed into monetary terms the value of the marginal product (VMP) is obtained, which can be compared with the relevant marginal factor cost (MFC) to deduce the efficiency of using respective resources. The estimated coefficients (b_i) indicate the responsiveness of the output to changes in the level of resources used in the production process, commonly referred to as the elasticity of production. Algebraically this is presented as:

$$\varepsilon = \left(\frac{\Delta Q}{\Delta X_i}\right) * \left(\frac{X_i}{Q}\right) = b_i \text{ ....} (3)$$

Where,

ε	=	elasticity of production
X	=	the amount of input used and
Q	=	the amount of output produced

$\frac{\Delta Q}{\Delta X_i}$ in the above equation is the marginal physical product (MPP) of the variable input (X_i), while $\frac{X_i}{Q}$ is the inverse of the average physical product (APP)

Results and Discussion

Input use levels in Rungwe district

Coffee production requires different types of inputs within one growing season in order to attain optimum production levels. Following market reforms, price of these inputs have increased beyond the reach of most farmers. This has led to low rates of application of inputs, (especially fertilizers). The results of fertilizer use levels in Rungwe district show that farmers in the sample applied fertilizers below the recommended rate (Table 1), due to high fertilizers prices. Most of them reported that they did not have cash to purchase farm input nor did they have credit.

Table 1: Fertilizer use levels in coffee farms in smallholder farmers in Rungwe district

Fertilizer used	Amount used	Recommended rate	Gap
Urea	60	100	40
CAN	75	160	85

Source: Survey data, 1997

Technical efficiency (Production Efficiency)

Technical efficiency evaluates the farmers' ability to obtain the maximum possible output from a given set of resources. A farm is said to be technically efficient if they produce as much output as possible from a given set of inputs or if the farmer uses the smallest possible amount of inputs for given levels of output. For this study, technical efficiency (TE) was calculated to estimate how effectively coffee farmers utilized their resources by computing the ratio of actual output to potential yield (Equation 4). On the basis frontier models, this type of analysis provides a measure of technical efficiency from the gap between potential and actual yield levels. The potential yields are based on results from research stations within Mbeya region as well as recommended by local Extension staff. Results of TE are a show in Table 2 below

$$TE = \frac{Actual \quad Yield}{Potential \quad Yield} \qquad \text{---} \qquad (4)$$

Table 2: Technical Efficiency and Yield gap of Coffee, Rungwe district

Average Actual yield (kg/ha)	Average Potential yield (kg/ha)	Yield gap (kg)	Average Technical Efficiency (percent)
619.50	1250	630.5	49.6

Source: Computed from Survey data, 1997

Results in Table 2 show that the technical efficiency of coffee farmers in the sample was 49.6%, which is far below the optimum efficiency level, presenting a yield gap of 630.5 kg/ha. Further analysis of the efficiently resource use by coffee farmers was done using the Cobb-Douglas production function, where key factors that influence the production of coffee were included.

Analysis of Efficiency in Resource Use and Productivity.

Production Function Estimation and analysis

The Cobb-Douglas production function specified in equation 2 above was estimated using Ordinary Least Squares. Results of the regression analysis are presented in Table 3.

Results of the estimation show that the adjusted R^2 is 0.56, which is statistically significant from zero at the at 5% level of significance. Although other important explanatory variables such as the age of coffee plants and the level of management were not included, the model explains 56 percent of the variation in total farm production from farmers, which is quite satisfactory for a cross sectional data set.

Table 3: Production elasticities of the respective factors of Production for coffee farmers, Rungwe district, 1996

Variable	Coefficient	t-value	t-Significance
Constant	11.446	5.364***	0.000
X_1 (land)	-0.132	-2.588**	0.011
X_2 (labour)	0.067	1.455	0.202
X_3 (Capital)	0.496	3.157**	0.003
F-ratio = 4.940**		SEE = 0.695	
R^2 adjusted = 0.561		D-W = 1.903	
$\sum b_i$ = 0.431 (Returns to scale)			
*** and **, Significant at the 1% and 5% level respectively			

Source: Computed from Survey data, 1997

The goodness of fit of the data could has been further improved had some explanatory variables, such as the age of the coffee plants and the level of farm management were included in the regression equation. However, it was not possible to obtain reliable information on these key variables due to poor record keeping for most farmers. Based on these results the hypothesis that all coefficients other than b_0 are zero should be rejected. From the specified variables, the elasticities of land and capital are statistically significant at 5% and 1% level for the coffee farmers respectively.

As stated earlier the estimated coefficients are the elasticities of production for each respective factor of production, showing on average, the percentage change in the value of output resulting from a unit percentage in the variable input.

Production economic theory stipulates that the larger the value of the constant term the more technically efficient the farmers are. Among the specified variables, capital and labor had the expected signs, being 0.5 and 0.07 respectively while that of land was – 0.32. These results imply that, capital had the potential to contribute more to output than any other variable among the coffee farmers. A one percent increase in capital is associated with a 0.49 percent increase in output of coffee, compared to only 0.07 percent for a one percent increase in labor. A similar increase in land will lead to a 0.13 percent decrease of output.

It is normally expected that an increased in cultivated area would be associated with increased gross output, so the sign of the coefficient for land should be positive. However, the negative sign could be associated with the fact that increased farm size diminishes the timeliness of input use. In fact, on large farms activities are spread over time. It therefore becomes more difficult for larger farmers than for smaller farmers to conduct their farm operations at the optimum times, hence inefficient use of fertilizer. Also given the importance of fertilizers in farming system and the low access to these inputs and their high cost, increasing the area cultivated implies spreading insufficient fertilizer very thinly.

The relatively high elasticity of production for fertilizer relative that of land and labor, could be due to the fact that coffee farmers are using lower levels of this inputs and substantial increase in production can still be realized by increasing the application rate. The relative importance of fertilizer in raising output is also identified by ranking the factors based on the magnitude of their absolute t-values, whereby fertilizer has the highest level of significance for the variation in coffee production among farmers.

Returns to scale are used measure the proportion by which output would be changed if all the factors of production change by a specific magnitude. Returns to scale are defined as increasing, constant or decreasing if the sum of the estimated elasticities (Σb_i) is greater than, equal to or less than unit respectively. Results from this study indicate that the sum of the elasticities (Σb_i) is less than unity (0.431), showing that the coffee farmers are experiencing decreasing return to scale. This implies that if all the inputs in the production of coffee double for example, output would increase by a factor that is less than two. Thus the size of farm operations could further increased to benefit from economies of size.

Another important issue here is how efficiently these farmers are organizing their production activities so as to maximize their profits given the prevailing input and output prices. In order to measure productivity of different agricultural resources, the value marginal products (VMPs) were computed.

Marginal Value of Productivity Measures

The VMP of resources were computed for only those resources whose regression coefficients were statistically significant in the production function. From the Cobb-Douglas production function, the marginal factor productivity can be computed from the estimated production elasticities and the average values of Q and X_i (Atieno, 1995) as follows;

$$VMP = b_i AVP = b_i \frac{Q}{X_i} P_Q \quad \text{--} \quad (5)$$

Where:

MVP = marginal value product for the given factor of production
b_i = the estimated elasticity of production for the i^{th} input;
VAP = the value of the average product;
Q_i = the total value of production
X_i = the value of the i^{th} input

The VMP gives the response per unit of factor input and enables the comparison of relative efficiency of resource use within the given farms. With all the variables (inputs and outputs) measured in monetary units using the market mean prices of coffee and fertilizer, the marginal products represent the net increase in gross income realized from the application of fertilizer. Using the estimated production elasticities and the average value of products (VAP), the VMPs were estimated and are presented in Table 4 below.

Table 4: Marginal Productivity Measures of the Specified Factors of Production for coffee Farmers; Rungwe district, 1996.

Variable	VMP	Significance
Land (TShs/ha)	90.9	Significant
Labour (TShs/ha)	46.1	Not significant
Capital (TShs/ha)	341.7	Significant

Source: Computed from Survey data, 1997

The marginal value product for capital input is highest at 342 Tshs per Shillings invested, implying that one additional shilling worth of capital inputs applied would add the equivalent of the VMP to coffee output. The high marginal value product of capital input among the coffee farmers can also be attributed to the high production elasticity of this resource relative to the low level at which it is used. Therefore, production levels could be substantially increased by increasing the level at which yield enhancing inputs such as fertilizer are used.

Marginal Return to Opportunity Cost Ratios (MROCRS)

The ratio of marginal returns to the opportunity cost of a resource (MROCRS) provides a measure of resource use efficiency prevailing on average within the sample. It is computed as the ratio of the value of the marginal product (VMP) to the marginal factor cost, which in a competitive market is is also equivalent to the unit price of the resource P_x. For profits to be maximized, this ratio should be equal to one ($P_yMPP/P_x = 1$). This means, the revenue from using one additional unit of input should be equal to the cost of acquiring that additional unit. A ratio of less than one means that too much of the resource is being used under the existing price conditions, implying inefficient resource use. If the ratio is greater than one, it indicates that too little of the resource is being used, and profit could be raised by increasing the level of resource use.

For a given resource that is used in production, its opportunity costs is equal to the market prices that prevailed on average during the production period. For land its rental value is used as the market price. The prevailing wage rate in the local market is used as the opportunity cost for labor. In this study, capital inputs included fertilizer, pesticides and herbicides. Their respective prices were used to compute the marginal unit price of capital goods for one acre, which came to Tshs 250. The price of labour is estimated using the average prevailing daily wage rate. The price of land could not be estimated because if land is transacted at all it always includes the value of permanent crops on it. The marginal cost for each resource and the computed efficiency of resource use is given in Table 5 below.

Table 5: Marginal Return to Opportunity Ratios for the Specified Resources among Coffee Farmers, Rungwe district, 1997

Resource	Px	MVP	MROCRS
land	-	90.94	-
Capital inputs	250	341.71	1.37
Labor	800	41.1	0.05

Source: Computed from Survey data, 1997

The results show that the Marginal return to opportunity ratios is greater than unity for all factors. These ratios indicate that too little of the respective resource inputs that is land and capital inputs are being used in relation to the prevailing market conditions. Hence the farmers' allocative efficiency is low using the available factors of production. Thus raising the level of these inputs should increase production per farm. Discussion with farmers revealed that the level of input use is very low because inputs prices are very high. Farmers lacked adequate cash, or credit facilities for purchasing agricultural inputs, which could improve crop productivity.

Conclusions and Recommendations

Findings of this study indicate that coffee farmers could increase coffee production and productivity by using more capital intensive inputs, especially fertilizer, which had the highest contribution to output gains compared to land or labor. However, due to high prices of these inputs and farmers' limited options for cash savings or credit forced then to cultivate larger areas and spread thinly the limited inputs they could access, which led to sub-optimum application rates. Meanwhile, coffee farmers experienced decreasing return to scale for the factors of production employed, implying that a one-percentage increase in the use of these factors would have led to a less than one- percent increases in the value of output. This again points to the potential for increasing inputs application rates.

Better utilization of resources is important and should be emphasized through increased use of capital intensive inputs such as fertilizers. However, under the prevailing situation with farmers faced difficulty to access such inputs due to high prices, and limited availability. Higher level of capital inputs application can be achieved if farmers working in collaboration with various agencies to form linkages for the purpose of improving access and use if agricultural inputs and training to ensure efficient utilization. Such training would enable farmers to form groups, associations or cooperatives that can have more bargaining power in procurement of inputs as well as in selling their products. Opportunities for expanding non-farm income sources should also be expanded since such income can be used to procure farm inputs. All these aspects should be built in to training programmes for farmers and extension agents

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