Sources of Technical Efficiency among Smallholder Maize Farmers in Southern Malawi

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Abstract

The agricultural sector in Malawi is vital to the economy for incomes and food security. The sector accounts for 35% of national income, generates 90% of foreign exchange, and provides paid and self-employment to 92% of the rural population. One constraint in achieving food security has been the small size and fragmented nature of land holdings among a large proportion of households in Malawi. Nonetheless, since independence there have been several attempts by the government to improve the productivity of food crops on small farms, particularly for maize, including the development of high yielding maize varieties, subsidization of farm inputs, provision of credit facilities, and the liberalization of both farm produce prices and farm produce marketing. While there have been several studies on food production in Malawi, the focus has mainly been on technology development and adoption, production constraints, the impact of structural adjustment policies, and the impact of price and marketing liberalization. This paper estimates technical efficiency among smallholder maize farmers in Malawi and identifies sources of inefficiency using plot-level data. We find that smallholder maize farmers in Malawi are inefficient; the average efficiency score is 46.23% and 79% of the plots have efficiency scores below 70%. The results of the study reveal that inefficiency declines on plots planted with hybrid seeds and for those controlled by farmers who belong to households with membership in a farmers club or association.

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1. Introduction

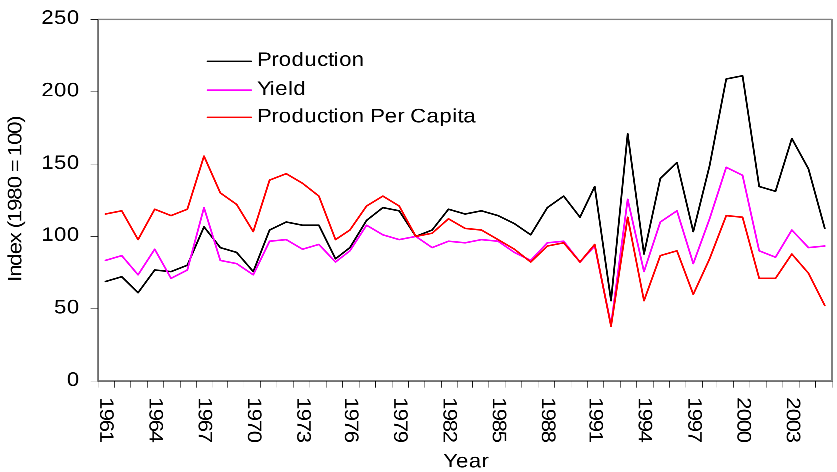
Central to economic activities in Malawi, the agricultural sector accounts for 35% of real gross product. It generates more than 90% of the country's foreign exchange earnings and provides paid and self-employment to 92% of the population. The government distinguishes between smallholder farmers and estate farmers, the latter being large-scale commercial operations (Malawi Government, 1987). The smallholder sector is divided into three categories: net food buyers, intermediate farmers and net food sellers. Net food buyers are those farmers with less than 0.7 hectare who cannot produce food to satisfy their subsistence needs given the technology they use and who thus remain dependent on off-farm activities. Intermediate smallholder farmers are those with land holding between 0.7 and 1.5 hectares who produce just enough for their survival but have very little for sale. Net food sellers are those farmers with land holdings of more than 1.5 hectares who produce more than their subsistence needs for survival during the year. Nearly 35% and 40% of smallholder farmers in Malawi fall in the categories of net food buyers and intermediate farmers, respectively. Alwang and Siegel (1999) note that about 70% of Malawian smallholder farmers cultivate less than 1.0 hectare and the median area under cultivation is about 0.6 hectares. About 70% of the land is devoted to maize, the main staple food crop. It is apparent that the success of the agricultural sector in Malawi is critical for raising living standards and for food self-sufficiency and as a sustainable source of livelihood for a large population.

Since independence in 1964, government agricultural policy has emphasized increasing the participation of Malawians in economic activities more generally and in improving the productivity of smallholder farmers (Malawi Government, 1971, 1987). The government food security and smallholder incomes' policy focused on increasing the productivity of maize, which is grown by almost 70% of smallholder farmers. According to the Malawi Government (1987: 9) it was observed that during the 1960s and 1970s, the principal determinants of productivity change were seen as the adoption of improved seed varieties, particularly hybrids, and the application of fertilizer. There was considerable public sector investment in a series of integrated rural development projects with a range of services introduced through these projects, including extension services and rural credit facilities. More particularly, there is evidence that technological developments such as seed variety development, fertilizer adoption and integrated farming systems have been central to these efforts in Malawi (Malawi Government, 1971, 1987; Smale, 1995; Smale et al., 1995; Lele, 1989), in addition to structural adjustment policies aimed at creating price incentives for crop production (Sahn and Arulpragasam, 1991).

The research problem

Maize is Malawi's main staple crop and therefore is of vital concern to agricultural policy decisions, food security and the overall development of both the agricultural sector and the economy. In the 1960s, 78% of cultivated land estimated to be under maize was monocropped with little fertilizer application (Malawi Government, 1971). In 1987, the government conceded that despite its investment in technology development and adoption, along with extension services, smallholder maize production had increased by only 2% between 1970 and 1986, with 1.2% attributed to expanded acreage (Malawi Government, 1987). The available studies on the productivity gains in maize production in spite of government investment in the agricultural sector suggest little improvement in productivity and the goal of self-sufficiency in food production remains a long-term target. Figure 1 shows no systematic trend in maize yield as measured by output per hectare. The maize yield improved marginally, particularly between 1961 and 1981, but then declined thereafter until the 1990s, when the oscillating pattern is more evident. Incidentally, the period after 1981 is associated with structural adjustment programmes in Malawi; this is the period in which maize yield witnessed a declining trend.

Figure 1: Maize production and yield indexes, 1961–2005



Source: Author's computation.

The food production trends are similar to the maize yield trend. The food production 1992, 1994 and 1997 are a result of adverse weather conditions in form of drought. This led to substantial maize imports in the 1990s in order to meet national food requirements. The picture that emerges from the per capita food production index reveals food insecurity over time, particularly in the 1980s, despite structural reforms that mainly targeted the agricultural sector.

These trends raise questions about the efficiency of maize production in Malawi even in periods when the country experiences favourable weather conditions. Why has maize productivity remained low in Malawi? Most existing studies in food production in Malawi relate to research on maize varieties and technological adoption (Smale, 1995; Smale et al., 1995; Zeller et al., 1998), the impact of structural adjustment programmes (Sahn and Arulpragasam, 1991; Kherallah and Govindan, 1999; Harrigan, 1988), and the liberalization of food produce pricing and marketing (Chirwa, 1998, 2000; Chilowa, 2000; Goletti and Babu, 1994; Kaluwa, 1992; Scarborough, 1990; Kaluwa and Chilowa, 1991; Mkwezalamba, 1989). Dorward (1999) analyses the relationship between farm size and productivity in smallholder agriculture in Malawi and provides evidence of a positive relationship between the two. However, there is apparent lack of empirical research on the productive or economic efficiency of smallholder farmers in the Malawian agricultural sector.

This study contributes to the understanding of resource use in smallholder maize producing farms in Malawi, while contributing to the empirical literature with respect to African agriculture more generally, and Malawian agriculture in particular. The study may also generate policy implications by identifying factors that are associated with technical efficiency in smallholder maize production.

Objectives

The main objective of this study is to estimate technical efficiency and identify the factors that explain variations in technical efficiency. The study has three specific objectives. First, the study estimates mean and plot-specific technical efficiency levels in smallholder farms producing maize, the main staple crop. Second, it examines the impact of technology adoption, such as improved seeds and fertilizer application, on the technical efficiency of smallholder farmers. Third, the study determines the relative role of farmer education, use of fertilizers, use of hybrid seeds, membership in an association and access to extension services.

2. Literature review

As a component of productive efficiency, technical efficiency is derived from the production function. Productive efficiency consists of technical efficiency and allocative or factor price efficiency. Productive efficiency represents the efficient resource input mix for any given output that minimizes the cost of producing that level of output or, equivalently, the combination of inputs that for a given monetary outlay maximizes the level of production (Forsund et al., 1980). Technical efficiency reflects the ability of a firm to maximize output for a given set of resource inputs, while allocative (factor price) efficiency reflects the ability of the firm to use the inputs in optimal proportions given their respective prices and the production technology. Developments in cost and production frontiers are attempts to measure productive efficiency as proposed by Farrell (1957). The frontier defines the limit to a range of possible observed production (cost) levels and identifies the extent to which the firm lies below (above) the frontier.

Estimating technical efficiency

The literature suggests several alternative approaches to measuring productive efficiency, grouped into non-parametric frontiers and parametric frontiers. Non-parametric frontiers do not impose a functional form on the production frontiers and do not make assumptions about the error term. These have used linear programming approaches; the most popular non-parametric approach has been the data envelopment analysis. Parametric frontier approaches impose a functional form on the production function and make assumptions about the data. The most common functional forms include the Cobb–Douglas, constant elasticity of substitution and translog production functions. The other distinction is between deterministic and stochastic frontiers. Deterministic frontiers assume that all the deviations from the frontier are a result of firms' inefficiency, while stochastic frontiers assume that part of the deviation from the frontier is due to random events (reflecting measurement errors and statistical noise) and part is due to firm specific inefficiency (see Forsund et al., 1980; Battese, 1992; Coelli et al., 1998).

The stochastic frontier approach, unlike the other parametric frontier measures, makes allowance for stochastic errors arising from statistical noise or measurement errors. The stochastic frontier model decomposes the error term into a two-sided random error that captures the random effects outside the control of the firm (the decision making unit) and the one-sided efficiency component. The model was first proposed by Aigner et al.

(1977) and Meeusen and van den Broeck (1977). Assuming a suitable production function, we define the stochastic production frontier as:

$$\ln\left(y_i\right) = f\left(x_{ij}, \beta\right) + \varepsilon_j \tag{1}$$

where y is the level of output on the jth plot, x is the value of input i used on plot j, $\varepsilon_i = v_j - u_j$ the composed error term, v_j is the two-sided error term, and u_j is the one-sided error term. The components of the composed error term are governed by different assumptions about their distribution. The random (symmetric) component v_j is assumed to be identically and independently distributed as $N(0,\sigma_v^2)$ and is also independent of u_j. The random error represents random variations in the economic environment facing the production units, reflecting luck, weather, machine breakdown and variable input quality; measurement errors; and omitted variables from the functional form (Aigner et al., 1977).

The distribution of the inefficiency component can take many forms, but is not symmetric. However, there is no a priori argument that suggests that one form of distribution is superior to another, although different assumptions yield different efficiency levels. The inefficiency component represents a variety of features that reflect inefficiency, such as firm-specific knowledge; the will, skills and effort of management and employees; and work stoppages, material bottlenecks and other disruptions to production (Aigner et al., 1977; Lee and Tyler, 1978; Page, 1980). Meeusen and van den Broeck (1977) and Aigner et al. (1977) assume that u_j has an exponential and a half-normal distribution, respectively. Both distributions have a mode of zero. Other proposed specifications of the distribution of u_j include a truncated normal distribution – $N(\mu,\sigma_u^2)$ (Stevenson, 1980) and the gamma density (Greene, 1980).

The stochastic model can be estimated by the "corrected" ordinary least squares (COLS) method or the maximum likelihood method. We follow the work of Battese and Coelli (1988,1995) using a Battese and Corra (1977) parameterization. The maximum likelihood (ML) estimates of the production function (Equation 1) are obtained from the following log likelihood function:

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

where ε_j are residuals based on ML estimates, N is the number of observations, $F()$ is the standard normal distribution function, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 / \sigma^2$. Assuming a half-normal distribution of u, the mean technical efficiency is measured by

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

where F is the standard normal distribution function. Measurement of farm level inefficiency requires the estimation of non-negative error u. Given the assumptions on the distribution of v and u, Jondrow et al. (1982) first derived the conditional mean of u

given ε. Battese and Coelli (1988) derive the best predictor of the technical efficiency of plot or farm j $TE_j = exp(-u_j)$ as

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

where $\sigma_A = \sqrt{\gamma(1-\gamma)\sigma^2}$. The maximum likelihood estimates of the production function in Equation 1 are automated in a computer programme, FRONTIER Version 4.1, written by Coelli (1996). FRONTIER provides estimates of β, $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\gamma = \sigma_u^2 / \sigma^2$ and average technical efficiencies, as well as plot or farm level efficiencies. FRONTIER also provides the estimate for μ when the symmetric error term follows a truncated normal distribution $u_j \sim N(\mu, \sigma_u^2)$.

Factors influencing technical efficiency

The literature suggests two methodological approaches for analysing the sources of technical efficiency based on stochastic production functions. The first approach is the two-stage estimation procedure in which first the stochastic production function is estimated, from which efficiency scores are derived. In the second stage the derived efficiency scores are regressed on explanatory variables using ordinary least square methods or tobit regression. This approach has been criticized on grounds that the firm's knowledge of its level of technical inefficiency affects its input choices; hence inefficiency may be dependent on the explanatory variables. The second approach advocates a one-stage simultaneous estimation approach as in Battese and Coelli (1995), in which the inefficiency effects are expressed as an explicit function of a vector of farm-specific variables. The technical inefficiency effects are expressed as

$$u_j = z_j\delta \tag{5}$$

where for farm j, z is a vector of observable explanatory variables and δ is a vector of unknown parameters. Thus, the parameters of the frontier production function are simultaneously estimated with those of an inefficiency model, in which the technical inefficiency effects are specified as a function of other variables. The one-stage simultaneous approach is also implemented in FRONTIER and in addition to the basic parameters the programme also provides coefficients for the technical inefficiency model.

Several factors, including socioeconomic and demographic factors, plot-level characteristics, environmental factors, and non-physical factors are likely to affect the efficiency of smallholder farmers. Parikh et al. (1995), using stochastic cost frontiers in Pakistani agriculture in a two-stage estimation procedure, find that education, number of working animals, credit per acre and number of extension visits significantly increase cost efficiency, while large land holding size and subsistence significantly decrease cost efficiency.

Coelli and Battese (1996), in a single estimation approach of the technical inefficiency model for Indian farmers, find evidence that the number of years of schooling, land size and age of farmers are positively related to technical inefficiency. Wang et al. (1996) use a shadow price profit frontier model to examine the productive efficiency of Chinese agriculture and find that a household's educational levels, family size and per capita net income are positively related to productive efficiency, but off-farm employment is negatively related to efficiency.

Tadesse and Krishnamoorthy (1997) report significant differences in technical efficiency across farm size groups, with paddy farms on small- and medium-sized holdings operating at a higher level of efficiency than large farms. They argue that because accessibility to institutional finance depends on asset position particularly land, small farms are forced to allocate their meagre resources more efficiently. Seyoum et al. (1998) use a one-stage model and find technical inefficiency to be a decreasing function of farmers' education and hours of extension visits to farmers participating in the modern technology project. Education does not significantly affect the efficiency of farmers using traditional farming methods.

Wadud and White (2000) apply a stochastic translog production frontier approach in both one-stage and two-stage technical inefficiency models. They find that inefficiency decreases with farm size and that farmers with good soils were significantly more technically efficient. Weir (1999) and Weir and Knight (2000) investigate the impact of education on technical efficiency in Ethiopia and conclude that household education positively influences the level of technical efficiency in cereal crop farms. Owens et al. (2001) explore the impact of agricultural extension on farm production and determine that access to agricultural extension services raises the value of crop production by 15% in Zimbabwe.

Existing empirical studies in Africa

The literature on productive or technical efficiency in African agriculture is emerging. Globally, however, there is a wide body of empirical research on the economic efficiency of farmers in both developed and developing countries (for reviews see Battese, 1992; Coelli, 1995). While the empirical literature on the efficiency of farmers is vast in developed countries and Asian economies, few studies focus on African agriculture. Heshmati and Mulugeta (1996) estimate the technical efficiency of Ugandan *matoke*-producing farms and find that they face decreasing returns to scale with mean technical efficiency of 65%. On the other hand, they find no significant variation in technical efficiency with respect to farm sizes. Nor do they identify the various sources of technical efficiency among *matoke*-producing farmers.

Seyoum et al. (1998) consider the technical efficiency and productivity of maize producers in Ethiopia and compare the performance of farmers within and outside the programme of technology demonstration. Using Cobb–Douglas stochastic production functions, their empirical results show that farmers who participate in the programme are more technically efficient with a mean technical efficiency equal to 94% compared with those outside the project whose mean efficiency equalled 79%. Also in Ethiopia, Weir (1999) investigates the effects of education on farmer productivity of cereal crops using average and stochastic production functions. This study finds substantial internal benefits of schooling for farmer productivity in terms of efficiency gains but finds a threshold effect that implies that at least four years of schooling are required to lead to significant effects on farm level technical efficiency. Using different specifications, average technical efficiencies range between 0.44 and 0.56, and raising education from zero to four years in the household leads to a 15% increase in technical efficiency. Moreover, the study finds evidence that average schooling in the villages (external benefits of schooling) improves technical efficiency.

The impact of education externalities on production and technical efficiency of farmers in rural Ethiopia is the subject of Weir and Knight (2000). They find evidence that the source of externalities to schooling is in the adoption and spread of innovations that shift out the production frontier. Mean technical efficiencies of cereal crop farmers are 0.55. A unit increase in years of schooling increases technical efficiency by 2.1 percentage points. One limitation of the Weir (1999) and Weir and Knight (2000) is that they investigate the levels of schooling as the only source of technical efficiency.

Using data envelopment analysis, Townsend et al. (1998) investigate the relationships among farm size, returns to scale and productivity for wine producers in South Africa. They find that most farmers operate under constant returns to scale, but the inverse relationship between farm size and productivity is weak.

Mochebelele and Winter-Nelson (2000) assess the impact of labour migration on the technical efficiency performance of farms in the rural economy of Lesotho. Using the stochastic production function (translog and Cobb–Douglas), the study finds that households that send migrant labour to South African mines are more efficient than those that do not, with mean inefficiencies of 0.36 and 0.24, respectively. In addition, there is no statistical evidence that the size of the farm or the gender of the household head affects the efficiency of farmers. These authors conclude that remittances facilitate agricultural production, rather than substitute for it. Their study does not, however, consider the many other household characteristics that may affect technical efficiency such as education, farmers' experience, access to credit facilities (capital) and advisory services, and the extent to which households that export labour receive remittances. The authors' interpretation that it is remittances that explain differences in technical efficiencies is based on the presumption that migrant labourers remit to their exporting households, and not on some measure of the extent of remittances.

Sherlund et al. (2002) investigate the efficiency of smallholder rice farmers in Côte d'Ivoire while controlling for environmental factors that affect the production process. Apart from identifying factors that influence technical efficiencies, the study finds that the inclusion of environmental variables in the production function significantly changes the results: the estimated mean technical efficiencies increase from 36% to 0.76%.

Binam et al. (2004) examine factors influencing technical efficiency of groundnut and maize farmers in Cameroon. They use a Cobb–Douglas production function to find mean technical efficiencies to be in the region of 73% and 77%. They also conclude that access to credit, social capital, distance from the road and extension services are important factors explaining the variations in technical efficiencies.

3. Methodology and data

A Cobb–Douglas stochastic production frontier approach is used to estimate the production function and the determinants of technical efficiency among smallholder maize farmers in Malawi. Given the potential estimation biases of the two-step procedure for estimating technical efficiency scores and analysing their determinants, the one-stage procedure is adopted following Battese and Coelli (1995). Because of the small sample size of farmers with plots that are purely mono-cropped, the Cobb–Douglas production function is specified while controlling for soil fertility. Although this approach has its own limitations, it remains one of the popular production functions in production frontier studies. The following model is estimated on the basis of the Battese and Coelli (1995) procedure:

$$\ln y_j = \alpha + \sum_{i=1}^{m} \beta_i \ln x_{ij} + \sum_{k=1}^{k} SQ_{kj} + v_j - u_j \qquad (6)$$

and

$$u_j = \delta_0 + \delta_j z_j + w_j \qquad (7)$$

where for plot *j*, *y* is the total quantity or value of maize produced, *x* is the quantity or value of input *i* used in the production process including labour, land, capital, quantity of fertilizers and quantity of seeds, *SQ* is a set of dummy variables for the quality of the soil, v_j is the two-sided error term, and u_j is the one-sided error term (technical inefficiency effects).

Indicators

Output is measured as the maize produced on a plot in kilograms; land is measured as the total plot area cultivated in hectares; and labour is estimated as person-days worked. Fertilizer is the amount of fertilizer used on the plot in kilograms. The quantity of fertilizer used on some plots was zero, so we used the approach in Sherlund et al. (2002) and equated the natural logarithm of zero to the logarithm of one-tenth of the smallest non-zero value in the sample (which turned out to be 1 kilogram of fertilizer used on the plot). Seed is the quantity of seed in kilograms, regardless of the type of maize seeds used on the plot. SQ is a three-category dummy variable representing quality of soils as identified by the smallholder farmers – poor, average and good soils. The inclusion of soil quality follows Sherlund et al. (2002) who find that environmental variables in the production function improve the estimated efficiencies.

The one-sided error term (the technical inefficiency effect) u_j is given in Equation 7 in which z is a vector of socioeconomic characteristics of the farmer and the plot and w_j is the error term. In this study, the farmer is defined as the household member who controls production activities on each plot used for the production of maize only (mono cropped maize plots). The socioeconomic and plot level characteristics modelled in the inefficiency effect include education, application of fertilizer, use of hybrid seeds, membership in a farmers club and access to extension services.

Data

The data used in this study were gathered through a smallholder farmer questionnaire administered to 156 households with information collected at household member level. The data collected include plot level output of maize and other food crops produced, the inputs used in the production process (land, capital, labour fertilizer and seeds) on each plot, and the socioeconomic and plot-specific characteristics.

The sample of smallholder farmers was drawn from one of the eight agricultural development divisions (ADDs). Machinga ADD in southern Malawi was purposively selected as one of the ADDs that devote a large percentage of cultivatable land to maize production. Mataya et al. (1999) note that nearly 48% and 45% of cultivatable smallholder land is allocated to maize production in Kasungu and Lilongwe ADDs, respectively – followed by Machinga and Blantyre ADDs. In the selected ADD, one rural development programme (RDP) or district – Machinga – was selected on the basis of the cultivatable land devoted to maize production. The selected RDP or district was stratified into traditional authorities (TAs) with each TA being further stratified into enumeration areas (EAs). Two traditional authorities in the selected district and two EAs in each TA were randomly selected for the administration of the questionnaire. At least 37 households in each selected EA were randomly selected, after a simple household listing.

In each of the selected households, the household head or a person with information about the farming activities of other household members was interviewed along with other individual members where necessary. The 156 households interviewed had a total of 444 plots used for the production of various crops including 206 plots used for maize production. Of the total 206 plots on which maize was the main crop, only 48 plots from 37 households were used purely for maize production. Since the output and input data were only collected with respect to the main crop grown on the plot, data from 48 plots on which maize is monocropped are used in this study.

4. Empirical results

Definitions of variables and descriptive statistics are summarized in Table 1. The level of education among maize farmers is low as revealed by the mean years of schooling of 3.5 years. Most of the plots on which maize is grown are small with the mean plot size of 0.35 hectares. This implies that most of the farmers interviewed were net food buyers. With the famine in the previous season, 2000/01, many households ate most of the maize while green to meet the food deficits in the pre-harvest season. Fertilizers were applied to 52% of the plots, while hybrid maize was the type of seed used on 48% of the plots. Only 6% of farmers come from households in which at least a member of the household has membership in a club or association, and only 35% of farmers had access to extension services.

The estimation of the Cobb–Douglas stochastic production function in Equation 6 simultaneously with the technical inefficiency effects in Equation 7 generates the results presented in Table 2. The parameter $\gamma = \sigma_u^2 / \sigma^2$ lies between 0 and 1; with a value equal to 0 implying that technical inefficiency is not present and the ordinary least square estimation would be an adequate representation and a value close or equal to 1 implying that the frontier model is appropriate (Piesse and Thirtle, 2000). The value of $\gamma = 0.5533$ is statistically significant at the 5% level, which implies that more than half of the residual variation is due to the inefficiency effect. The one-sided generalized likelihood ratio tests of $\gamma = 0$ provided a statistic of 17.04 distributed as χ^2 with seven degrees of freedom, which is statistically significant at 1% level, indicating that the average production function is not a suitable specification of maize production and technical efficiency effects are not random errors.

All the coefficients of the inputs in the production function are positive, but only labour is statistically significant at the 10% level. Thus, labour is the most significant input in the production of maize. This is expected since most of the maize production in Malawi uses traditional technology that relies heavily on family labour. The indicators of the quality of soils based on subjective judgements of the farmers are statistically significant at 5% level where soil quality was judged fair and at the 10% level where the soil quality was judged good. The estimated return to scale is 0.97, implying that maize is produced close to constant returns to scale on the sample plots.

Table 1: Definition of variables and descriptive statistics

Variable	Description	Mean	SD
Production function			
ln maize	Natural log of the quantity of maize cultivated (kilograms)	4.385	1.131
ln land	Natural log of the plot size under maize cultivation (hectares)	-1.041	0.895
ln capital	Natural log of the value of capital at current cost used on the plot (Malawi Kwacha)	5.820	0.819
ln labour	Natural log of family and hired labour used (man-days)	3.418	1.216
ln fertilizer	Natural log of the quantity of fertilizer (kilograms)	0.313	2.698
ln seed	Natural log of the quantity of seeds (kilograms)	1.835	1.005
SQ – fair	Dummy: 1 if soil quality was judged average by farmer	0.229	0.425
SQ –good	Dummy: 1 if soil quality was judged good by farmer	0.271	0.449
Inefficiency model			
education	Number of years of schooling for the farmer	3.458	3.408
fertilizer	Dummy: 1 if the farmer used fertilizer on the plot	0.521	0.505
hybrid	Dummy: 1 if the main type of maize on the plot is hybrid	0.479	0.505
club	Dummy: 1 if any of the members of the household belongs to a club or association	0.063	0.245
extension	Dummy: 1 if the farmer had access to extension services – farmers was at least visited by extension workers.	0.354	0.483

Source: Author's computation.

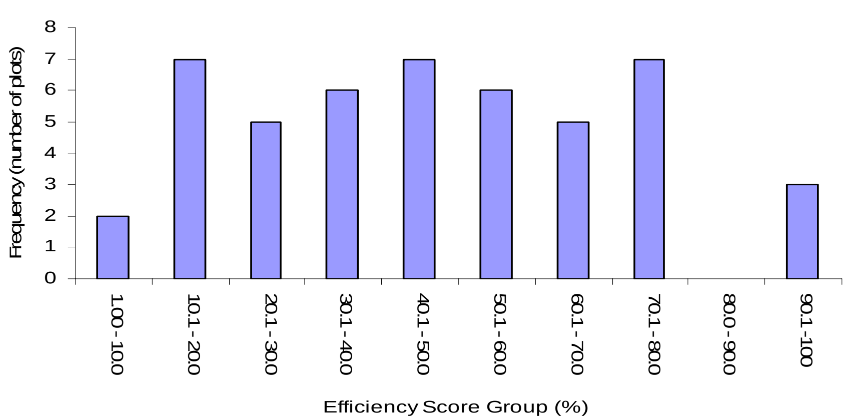
The mean technical efficiency level among smallholder maize farmers is 46.23, with a standard deviation of 23.3% and a range from 8.12 to 93.95%. Figure 2 presents the distribution of the technical efficiency levels. The modal groups are the efficiency levels 10.1–20.0, 40.1–50.0 and 70.1–80.0%; only 20.9% of the pure maize plots have technical efficiency scores of more than 70%. The mean levels of efficiency are low but comparable to those from other African countries. For example, Seyoum et al. (1998) find the mean technical efficiency of maize producers in Ethiopia to be 79%. Weir (1999) and Weir and Knight (2000) find mean efficiency levels of about 55% among Ethiopian cereal crop producers, while Mochebelele and Winter-Nelson (2000) find average technical efficiencies of between 64% and 76% in Lesotho.

Table 2: Maximum likelihood estimation of the production frontier with inefficiency model (dependent variable: ln *maize*)

Variables	coefficient	t-ratio
Production function		
constant	2.4858**	2.5868
ln *land*	0.1764	1.0667
ln *capital*	0.2584	1.5862
ln *labour*	0.2413*	1.7031
ln *fertilizer*	0.1143	1.1425
ln *seed*	0.1800	0.1090
SQ- fair	0.6923**	2.4416
SQ – good	0.7407*	1.9617
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.6173***	3.1169
$\gamma = \sigma_u^2 / \sigma^2$	0.5533**	2.3617
Log likelihood	-50.874	-
Returns to scale (RTS)	0.97	-
Number of plots	48	-
Inefficiency model		
constant	1.1045*	1.9617
education	0.0337	0.5631
fertilizer	0.0942	0.1473
hybrid	-1.2259***	-3.5372
club	-5.3472***	-3.5160
extension	0.6637	1.6001

*** Statistically significant at 1% level
** Statistically significant at 5% level
* Statistically significant at 10% level
Source: Author's computation.

Figure 2: The distribution of efficiency indexes among smallholder maize farmers



The technical inefficiency model shows that two of the five variables are statistically significant at the 1% level. The coefficient of education is positive but statistically insignificant, suggesting that better educated farmers produce maize inefficiently, which is contrary to expectations. One explanation is that maize is mainly produced for subsistence using traditional methods and the education of farmers does not play a role in the optimal combination of inputs. Similarly, the dummy representing adoption of fertilizers is statistically insignificant, given that almost half of the smallholder farmers in the sample adopted this technology. It is quite possible that although some farmers did use fertilizer technology, given the low level of education among most farmers and the small land holdings, they may have applied it inappropriately. Dzimadzi et al. (2001) in the case of a targeted input safety net programme find that problems of literacy and numeracy led farmers to use the inputs inappropriately. In some cases, inputs were used on larger areas than the technical specifications contained in the leaflets and in other cases the instructions conflicted with the traditional farming systems. Sibale et al. (2001) find that only 50% of respondents followed the targeted inputs programme instructions for planting maize.

The coefficient of the dummy representing use of hybrid seeds is statistically significant at the 1% level. Plots with hybrid maize seeds are more efficient than plots using local seeds. Local maize seeds are usually preferred by most smallholder farmers because of the quality of maize flour produced through the traditional system, fewer demands on fertilizers and ease in storage – it is not susceptible to pests and it can be recycled as seed (Smale, 1995). As a result, despite major investments in research and development to produce high yielding maize seeds, most farmers in Malawi still prefer local maize to improved maize.

The coefficient of the dummy variable for membership in a farmer club is statistically significant at the 1% level. Club membership is part of social capital. Binam et al. (2004) also use club membership to capture the role of social capital in providing incentives for efficient farm production and find similar results. The sharing of information on crop husbandry information at club or association level tends to filter to other members of the households that are not members or through demonstration effects of farming practices on club or association members' plots. Thus club membership has some external effects on family members who are not members of the farming clubs.

The relatively low levels of technical efficiency among smallholder maize farmers in southern Malawi point to the need to pursue policies that enhance the organization of farming systems in the country. One of the main constraints facing agriculture in Malawi is the small size of the land holdings, which are becoming smaller and smaller through subdivision to family members. Given that maize is the main staple food in Malawi, food production efficiency and food security can be enhanced through policies that increase the utilization of the existing small holdings by promoting adoption of high yielding maize varieties and by promoting networks among farmers. For a long time, from independence to 1992, smallholder agriculture was largely organized around farmers clubs for effective delivery of extension services and agricultural credit. The farmer club system collapsed in 1992 following the collapse of the agricultural credit scheme that worked through the club system and only a few farmers today belong to farmers club or association. The significance of club membership found in this study points to the need for the revival of the farmer club system or the development of farming cooperatives in Malawi.

5. Conclusions

This study set out to estimate levels of technical efficiency in maize production among smallholder farmers in Malawi. Since maize is the main staple food in Malawi, high productivity and efficiency in its production are critical to food security in the country. The government has been investing in agricultural development since independence in 1964, but most households remain food insecure and aggregate maize production indexes do not show sustainable patterns in food production. The stochastic production function approach was used to estimate technical efficiency scores at plot level while simultaneously determining the factors that are associated with efficiency using maize production data on monocropped plots from southern Malawi.

The econometric results based on the stochastic production function show that maize production is done under constant returns to scale. Many smallholder maize farmers are technically inefficient, with mean technical efficiency scores of 46.23% and technical scores as low as 8.12%. The mean efficiency levels are lower but comparable to those that obtain in other African countries whose means range from 55% to 79%. The results, however, support the hypotheses that technical efficiency increases with the use of hybrid seeds and club membership. Surprisingly, one of the variables used for capturing adoption of technology shows that the application of fertilizers does not explain the variations in technical inefficiency. This may imply that most farmers using these technologies use them inappropriately on small land holdings.

Despite the long history of government investment in the agriculture sector through extension services and promotion of technology, smallholder maize farming remains uneconomic and technically inefficient. Two main policy issues emerge from the results of this study. First, there is need to promote adoption of hybrid seeds among smallholder maize farmers. The government policy of subsidizing hybrid maize seeds and fertilizers since the 2005/06 agricultural season is consistent with the findings of this study. Second, there is need to enhance social capital in smallholder farming through the revival of farmers clubs or through the creation of agricultural cooperatives. Our results are based on a small sample of smallholder farmers in one of the districts in southern Malawi and may not necessarily be representative of the entire smallholder sector with its varying land holding sizes in different ecological zones. Furthermore, it was not possible to control for differences in the family life cycle and the natural abilities of farmers through fixed effects modelling due to the limited number of plots cultivated by the farmers or households.

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