ABSTRACT
The idea that smallholder farmers are reasonably efficient has triggered much debate in Sub-Saharan Africa. Indeed, efficiency of smallholder farmers has implications for choice of development strategy; reason being that Sub-Saharan countries derive over 60% of their livelihoods from smallholder agriculture and rural economic activities. This paper evaluates factors that promote production efficiency among smallholder farmers in Kenya as avenues for policy intervention. A production frontier function was fitted to a random sample derived from a survey carried in 2007. Results show that all conventional inputs had the expected significance. On the inefficiency indicators, ownership to farmland, attendance to agricultural workshops, access to credit and participation in self-help groups significantly reduced inefficiency, while age, market distance, female gender and formal education increased inefficiency. Our findings suggest that within the available technologies, farmers can improve on their productivity if they nurture teamwork as in groups where labour is shared. Besides, better roads would reduce transaction costs and promote higher returns, and training in agriculture would boost efficient resources use for better performance. Therefore, there exists opportunity to improve efficiency in production given existing farm technologies.

KeyWords: Technical Efficiency, Smallholder Farmers, Africa
1 INTRODUCTION

The idea that smallholder farmers are reasonably efficient in allocating their resources and respond positively to price incentives has triggered much attention, particularly in Sub-Saharan Africa. Indeed, the level of efficiency of smallholder farmers has important implications for choice of development strategy; reason being that most of Sub-Saharan countries derive over 60% of their livelihoods from agriculture and rural economic activities. If farmers are sufficiently efficient then increases in productivity require new inputs and technology to shift the production possibility frontier upward. But, on the other hand, if there are significant opportunities to increase productivity through more efficient use of farmers’ resources and inputs with current technology, a stronger case could be made for productivity improvement through ameliorating the factors or determinants of inefficiency.

In Kenya, agriculture still plays a major role in the economy with considerable resources invested on new inputs and technologies under the agricultural extension program. Agriculture accounts for about 30% of the country’s Gross Domestic Product (GDP), over 60% of exports, 75% of the total labour force, and over 80% of industrial raw materials (Gok 2006). Nevertheless, empirical evidences on farmer efficiency are very scanty and little work has been done in these respects. Particular area of interest is the role of rural credit systems in improving inputs a locative efficiency. Further more, despite the fact that smallholder farmers in Kenya face constraints in improved inputs acquisition, little effort has been made to identify constraints to efficient use of such resources once they are at the disposal of farmers. Motivations of this paper are, therefore, to determine factors causing inefficiency among smallholder farmers. The rest of this paper is organized as follows; in section 2, we provide some background on source of the study area, with section 3 introducing the conceptual framework and econometric modeling. Section 4 presents results, with relevant examples on technical efficiency indicators. The final section draws conclusions and derives policy recommendations.

2. CONCEPTUAL FRAMEWORK

The assumption that all producers are market oriented and producing for commercial purposes, lead to the concept of competitive market situation, with more efficient users of inputs driving less efficient ones out of the market. In this theoretic framework, all farmers are assumed to face the market for inputs even if they have to produce for subsistence purposes. The premise being that even with subsistence production the household needs to overcome food security and will be motivated to use improved inputs and face product markets when they strive to meet their food security needs. Therefore, farmers need to be efficient in production to survive and earn a decent living both on farm and on off-farm investment. The literature on smallholder agriculture in Kenya Degoote (1996), Salasia et al, (2001) and Odendo et al. (2000) indicate that public policy support technological adoption, credit investment to agriculture and intensification to improve productivity. However, production efficiency conventionally measured in terms of farm financial gains inform of gross margins hide a lot of information such as farm household specific characteristics, extension access, input and product market transaction costs and even credit market effects (Delgado 2003). Therefore, to overcome the limitations above a stochastic frontier production function is modeled to appropriately capture effects of inefficiency variables in production process, particularly where
farmers are operating under different farm scales, market access, credit, wealth endowments and personal variations in knowledge. Within the context of farm production, efficiency is defined as the ability to achieve the highest possible income, given conventional factors of production, fixed factors of the farm and other socio-economic variables specific to the farm household. Therefore, production efficiency represents the best practice of the farm household for any given inputs. Stochastic frontier function was first proposed by Aigner et al. (1977) and Meeusen & van den Broeck (1977). It is expressed as:

\[
Q_i = Q(X_i; \beta) \cdot \varepsilon^\mu \quad \text{(1)}
\]

Where \(Q(X_i; \beta)\) and \(\varepsilon^\mu\) represent the deterministic and stochastic parts of the function, \(\mu\) represents the random error term, and \(\beta\) is a vector of parameters to be estimated. Such model provides a great virtue in the sense that, it enables researcher to separate the random error component from variations in technical efficiency. Thus, following Kumbhakar & Lovell (2000), the upper bounded production frontier may be estimated by postulating that the error term contains two independent components: one sided error term (\(U\)) representing economic efficiency and the random error with normal properties found in all regressions. Consequently, following the above, the total error can be decomposed into its respective two components as below:

\[
\varepsilon_i = v_i + u_i \quad \text{-------------------------------------------- (2)}
\]

where \(V\) is the symmetric error term accounting for random variations in output due to factors outside the control of the farmer such as weather, disease, bad luck and measurement error, where as \(U\) represents the technical inefficiency relative to the stochastic frontier, which assumes only positive values. The distribution of the symmetric error component \(V\) is assumed to be independently and identically distributed as \(N(0, \sigma_v^2)\). However, the distribution of the one sided component \(U\) is assumed to be half normally \((U > 0)\) distributed as \(N(0, \sigma_u^2)\) and thus measures shortfalls in production from its notional maximum level. If \(U = 0\), then the farm lies on the frontier obtaining maximum output given variable and fixed inputs. But, if \(U > 0\), then the farm is inefficient and makes losses. Therefore, the larger the one sided error the more inefficient the farm is. Equation 1 can then be rewritten as:

\[
Q_i = Q(X_i; \beta) \cdot \exp\{v_i\} \cdot \text{Eff}_i \quad \text{---------------------------- (3)}
\]

With two parts: \(Q(X_i; \beta)\), which is a deterministic part common to all producers, and a producer specific part \(\exp\{v_i\}\), which captures the effect of random noise or shock on each producer. Therefore, technical efficiency (\(\text{Eff}_i\)) becomes:

\[
\text{Eff}_i = \frac{Q_i}{Q(X_i; \beta) \cdot \exp\{v_i\}} \quad \text{--------------------------------------------- (4)}
\]

Which is the ratio of observed output to maximum feasible output in an environment characterized by \(\exp\{v_i\}\). Equation 4 implies that \(Q\) achieves its maximum feasible value of \([Q(X_i; \beta) \cdot \exp\{v_i\}]\) if and only if \(\text{Eff}_i = 1\). Otherwise, if \(\text{Eff}_i < 1\) provides a measure of the short-fall of observed output from maximum feasible output in an environment characterized by \(\exp\{v_i\}\) which varies across smallholder farmers, and \(\beta\), as in above, is a vector of parameters to be estimated. Assuming that \(Q(X_i; \beta)\) takes the log-linear Cobb-Douglas functional form, the stochastic production frontier model in Equation (1) could be rewritten as:
\[
\ln Q_i = \ln Q(X_i; \beta) + v_i - u_i \quad \text{................. (5)}
\]

Where \( e_i = v_i - u_i \) is the composed of the two-sided 'noise' component \( v_i \) \((v \sim N(0, \sigma_v^2))\) and the one-sided efficiency component \( u_i \geq 0 \) with half-normal distribution \((u \sim N(0, \sigma_u^2))\) and assumed to be independent of each other. Maximum likelihood estimation of Equation (5) yields estimators for \( \beta \) and \( \lambda \), where \( \beta \) is as defined earlier, \( \lambda = \sigma_u^2 / \sigma_v^2 \) (is an efficiency indicator) and \( \sigma^2 = \sigma_u^2 + \sigma_v^2 \) (represent the total variance). If \( \lambda \) is closer to zero then the symmetric error term dominates the variation between the frontier level of output and the observed level of output. Thus, a value of \( \lambda \) close to zero implies that the discrepancy between the observed and the maximum attainable levels of output is dominated by random factors outside the control of the producer. Otherwise, the more \( \lambda \) is greater than one the more the production is dominated by variability emanating from technical inefficiency. Once the parameters of the stochastic frontier model are estimated using MLE (Battese & Coelli 1992), then the Jondrow et al (1982) decomposition technique can be used to obtain farmer-specific estimates of inefficiency \( \hat{u}_i \). That is the above-mentioned assumptions on the statistical distributions of \( V \) and \( U \) would allow us to generate the conditional mean of \( u_i \) given \( e_i \) as below:

\[
E(u_i / e_i) = \sigma^* \left[ \frac{f^*(e_i; \lambda / \sigma)}{1 - F^*(e_i; \lambda / \sigma)} - \frac{e_i \lambda}{\sigma} \right] \quad \text{.................(6)}
\]

where \( F^*() \) and \( f^*() \) are the standard normal cumulative and standard normal density functions respectively, evaluated at \( e_i \lambda / \sigma \), and \( \sigma^2 = \sigma_u^2 / \sigma_v^2 \), for \( \lambda \) as defined above. So that, Equations (5) and (6) provide estimates for \( V \) and \( U \) after replacing \( e, \sigma, \) and \( \lambda \) by their estimates.

There are two estimation approaches used in estimating production frontier function. The first estimation approach is known as two-step procedure. In the two step procedure, farm specific inefficiency is estimated using stochastic frontier function and then predicted inefficiencies are regressed with farm socio-economic variables or inefficiency variables to identify reasons for inefficiencies (Battese & Coelli 1989). The second estimation is known as a single step approach. This is where a stochastic frontier model is used in which the inefficiency effects \((U_i)\), are expressed as an explicit function of a vector of farm specific variables and a random error and parameters are estimated simultaneously (Coelli 1995). The two-step approach assumes that the elements of inefficiency \( z_q \) are uncorrelated with conventional factors \((X_i)\). Maximum likelihood estimates of \((\beta, \sigma_v^2, \sigma_u^2)\) from Equation (5) under such assumption are biased and inconsistent, unless the \( X_i \) and \( Z_i \) variables are true orthogonal. In its second stage an attempt is made to explain \( U \) using a set of \( Z_i \) variables which is a contradiction (Kumbhakar & Lovell 2000).

Therefore, we employ the single stage approach, as in Coelli (1995), where socio-economic variables are incorporated directly in the frontier function. Here the \( Z_i \) factors affecting technical inefficiency are included directly in the production function, and specified as

\[
\ln Q_i = \ln Q(X_i, Z_i; \beta) + v_i - u_i \quad \text{....................... (7)}
\]
With \( z_q \) variable measured in log form, the marginal effects of \( Z \) variables on output could be determined as:
\[
\frac{\delta \ln Q}{\delta \ln z_q} = \gamma_q \tag{8}
\]
which also implies that:
\[
\frac{\delta y}{\delta z_q} = \frac{\gamma_q Q}{z_q} \tag{9}
\]
In this approach \( Z \) will presumably have two effects: one, it shifts the production technology upward or downward depending on the sign of \( \gamma \); two, it increases or decreases output through reducing or increasing technical inefficiency. Battese & Corra (1977) show the log likelihood under the above parametization is equal to:
\[
\log (L) = -\frac{N}{2} \log(\frac{\sigma_2}{2}) - \frac{N}{2} \log(\sigma^2) + \sum_{i=1}^{N} \log[1 - \Phi(z_i)] - \frac{1}{2\sigma^2} \sum_{i=1}^{N} (y_i - x_i\beta)^2 \tag{10}
\]
Where: \( z_i = \frac{(y_i - x_i\beta)}{\sigma} \sqrt{\frac{\lambda}{1-\lambda}} \) and \( \Phi \) is the distribution function of a standard normal random variable. The maximum likelihood estimates of \( \beta, \sigma^2, \phi \) are obtained by maximum of the log likelihood estimation in stata. The maximum likelihood estimates are consistent and asymptotically efficient (Aigner et al. 1977). We therefore empirically estimate a normalized stochastic frontier Cobb-Douglas function; normalized by the natural logarithms. The function includes both the conventional production factors and socio-economic factors affecting production inefficiency. The specific empirical model is estimated as:
\[
\ln Q = \beta_0 + \sum \beta_i X_{ij} + \nu_i - \nu_i \tag{11}
\]
and
\[
\nu_i = \alpha_0 + \sum \alpha_i Z_{ij} \tag{12}
\]
Where \( Q \) is farm households’ total income from productive activity (farm and non-farm income), \( X_i \) is as defined earlier (is a vector of conventional production variable and fixed factors), \( \nu_i \) is the inefficiency measure, \( Z_i \) is a vector of socio-economic factors affecting inefficiency. The \( X_i \) variables are fertilizer, feeds, chemical inputs, business purchases, labour inputs, fixed inputs such as implements, land area and livestock assets, while \( Z_i \) variables are access to credit, age, education, extension, attendance to seminars, gender if female, time spent on off farm activity, and ownership of title to land.

### 3. MATERIALS AND METHODS

The study covered two districts in Kenya, namely Nakuru and Kakamega districts, with a total sample of 600 farmers sampled. Kakamega District is located in Western Kenya around Lake Victoria categorized as Moist Mid-altitude (MM) zone (Hassan, 1998). The area produces moderate yields. Elevation ranges between 1110-1500 meters. The district ranks second among districts with the largest overall number of households living below poverty line ie. 64.5% of households live below poverty line (RoK, 2005). The District also ranks third among districts with the highest rural absolute poverty. Efforts therefore to raise productivity of the people here would reduce the poverty levels, and act as representative for similar areas in developing economies. Nakuru District falls within the Highland Tropics (HT). The zone has high crop yields and cover 30% of the country area. Elevation ranges between 1600-2900 meters. Nakuru District is proposed because it is one of the districts in the high tropics that harbor many different cropping and livestock activities and viewed as the bedrock of food security in Kenya. It serves as a representative cosmopolitan agricultural district, where land subdivision has
gained great interest, and where different communities coexist. It also represents high potential areas in Kenya. On poverty, Nakuru District ranks twelfth, with 46.2% of households below poverty line (ROK, 2005).

4. RESULTS

4.1 Factors Influencing Production

Among the conventional factors with significant effects on output were investment in fertilizer, feeds, hired labour, farm size and value of equipment. The significant effects on value of fertilizer and feeds depict the role of improved inputs in production. Studies by Degroote et al. (2001) and Odendo et al. (2002) in Kenya support these findings. These results also indicate that among the resource poor farm households fertilizer and feeds are still major constraining factors in enterprise productivity. Planting materials and investment in crop chemical are also positive though insignificant. A study by Owuor (2002) among maize farmers in Siaya Kenya found that smallholder farmers rarely use chemicals in crop enterprises, and if they use, the amounts are negligible. The results on the insignificance of chemicals could also be explained by the fact that as households use inorganic fertilizer and hire more labour their crops and livestock enterprises overcome incidences of opportunistic diseases and pests. Consequently, reducing impact of chemicals on production. Results on the significance of hired labour points at the importance of rural labour market in agricultural production.

4.2 Factors that constrain Technical Efficiency

Factors that significantly reduce inefficiency are access to credit, age of the decision maker, group memberships and land ownership. On the contrary, female gender, size of the household and distance to the market significantly increase inefficiency. Education also increases inefficiency against expectations. The negative effects of credit on production inefficiency offer characterization of the degree of market development or competitiveness. Credit access indicates increased liquidity, which is a prerequisite for flexibility in purchase of improved inputs. Our findings thus point at the ease in allocation of purchased factors such as fertilizer, improved planting materials and hired labour in circumstances where credit is available.

Results on age show that older farmers are not able to use up to date farm management methods or are less adaptive to modern technologies. They prefer to be associated with older methods of production thus reducing efficiency. Similar results on effect of age on adoption of new technologies have been reported in a study by Owuor et al. (2004). In their survey, they observed that older households prefer to grow local varieties that are less productive, with indications that the old in Africa has strong cultural attachments to traditional production methods that reduce their production efficiencies in the modern times. Education on the other hand, increases inefficiency against expectations. This is counterintuitive as human capital is expected to produce positive impacts. One possible explanation is that technical skills in agricultural activities, especially in developing countries, are more influenced by ‘hands on’ training in modern agricultural methods other than the formal schooling as used in this study. Years of formal schooling referred to hear is of general nature and may not be significant in improving technical management in the farm. Thus, the most important training is agricultural training.
Significance of exposure to agricultural seminars depicts impact of access to technical knowledge and information in agriculture. Therefore, community based group training programmes could be an important intervention avenue for improving agricultural technical knowledge among farmers. Also related to education is extension contact. This is however insignificant, probably due to limited extension personnel in the rural areas following reduction in the government extension personnel in the last decade. Our results also reveal that out of a total sample of 600 farmers, only 167 received extension visit.

The significant effects of land ownership on inefficiency is a possible indicator for flexibility in use of inputs, and accessibility to credit markets. Ownership of land enables households to access other markets such as credit market for investment in production thus reducing poverty levels. This shows the predominant association between constrained landholding and rural poverty, suggesting that for households with inadequate access to land to earn a livelihood from agriculture, necessary intervention to make them own land is important. A survey on the access to land by different poverty categories in Kenya reveals that land is strongly associated with household per capita income (Gamba et al. 2006).

The effects of membership of self-help groups in reducing inefficiency indicate the role of community based social networks in improving transmission of technologies and probably in sharing of labour among farmers. Literature on group networks show that rural groups have advantages of enforcing sanctions, sharing experiences through free flow of information and at times sharing labour. This is a strong indication of the effects of social capital in ameliorating inefficiency problems resource utilization. Rural social networks help in overcoming impediments to information flow due to social divergence: the phenomena whereby individuals are more likely to communicate with those with similar incomes, education, ethnicity and social status as themselves, rather than with people from a diverse range of backgrounds (Grafton et al. 2004a, b). The more the people interact with each other, the better the information they will have about each other, making it easier to access extension services and other inputs at a cheaper cost, and in improving their productive efficiency. Group interactions also improve flow of information about best production methods, a factor that makes introduction of new technologies more feasible, hence increasing the level of productivity.

Positive effects of distance on production inefficiency shows that proximity to input and product markets matters for efficiency in line with the spatial economic theory. Distance relates to changes in transaction costs and in accessing farm inputs as well as accessing markets for the farm produce, which negatively affect efficient use of such resources and consequently less net returns from production. The effects of household size on inefficiency was expected to have either positive or negative effects, reasons being that larger households are likely to easily provide more labour in agriculture. On the other hand, larger households indicate high dependency ratios that may reduce efficient use of resources such as cash for investment in inputs. However, our results indicate positive effects, pointing at the latter hypothesis. The larger the household size the lower the inefficiency in input use. As the household becomes larger, the dependency levels increase infringing on the cash resources for acquisition of improved inputs, with consequent inefficiency.

Results on household headed by female indicate less efficiency. The probable reason could be the low levels of education among women in rural areas that reduces their ability to conceptualize technological information. In addition, the positive effect of female gender on production inefficiency may reflect lack of ownership to property, a factor that is common in
African rural communities. Women in Africa have no legal right to property, making them unable to offer asset securities to access markets for inputs. This differential access to productive assets and inputs constitutes a distortion in the sense that women’s activities are under resourced and under capitalized while male activities are comparatively well capitalized. Due to declining marginal returns and the loss associated with talented women being starved of economic resources aggravates output declines. Such gender gaps might not only lead to static inefficiency but also reduce efficient investments in new technologies and maintenance and improvement of assets, particularly land. Because of this, they are unable to take advantage of productive investment opportunities, which also reduces their per capita earnings.
Table 1: Maximum likelihood estimates of parameters of the normalized stochastic frontier production function and inefficiency model for smallholder farmers in Kenya.

<table>
<thead>
<tr>
<th>Dep: Ln of income from productive activity</th>
<th>Pooled Data</th>
<th>High Tropics Nakuru</th>
<th>Low Tropics Kakamega</th>
<th>OLS Estimates Pooled data</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>600</td>
<td>300</td>
<td>300</td>
<td>600</td>
</tr>
<tr>
<td>Wald Chi Square</td>
<td>304.01***</td>
<td>187.54***</td>
<td>158***</td>
<td>F&gt;20.10***</td>
</tr>
<tr>
<td>Prob Chi2</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>Rsq0.557</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-820.024</td>
<td>-408.616</td>
<td>-380.894</td>
<td>MSE=0.993</td>
</tr>
<tr>
<td>ln of fertilizer</td>
<td>0.060***</td>
<td>0.078***</td>
<td>0.040**</td>
<td>0.063***</td>
</tr>
<tr>
<td>ln of value of feeds</td>
<td>0.035***</td>
<td>0.043***</td>
<td>0.010**</td>
<td>0.037***</td>
</tr>
<tr>
<td>ln of value of planting materials</td>
<td>0.009</td>
<td>0.002</td>
<td>0.000</td>
<td>0.015</td>
</tr>
<tr>
<td>ln of value of vet/crop chemical</td>
<td>0.018</td>
<td>0.037**</td>
<td>0.001</td>
<td>0.020*</td>
</tr>
<tr>
<td>ln of business income</td>
<td>0.088***</td>
<td>0.133***</td>
<td>0.069***</td>
<td>0.090***</td>
</tr>
<tr>
<td>ln of value of hired labour</td>
<td>0.034***</td>
<td>0.039***</td>
<td>0.027**</td>
<td>0.037***</td>
</tr>
<tr>
<td>ln of family labour</td>
<td>-0.078**</td>
<td>-0.121**</td>
<td>0.035</td>
<td>-0.066**</td>
</tr>
<tr>
<td>ln of land size</td>
<td>0.304***</td>
<td>0.196**</td>
<td>0.392***</td>
<td>0.309***</td>
</tr>
<tr>
<td>ln of value of livestock assets</td>
<td>-0.001</td>
<td>-0.020</td>
<td>0.016</td>
<td>0.001</td>
</tr>
<tr>
<td>ln of value of equipment</td>
<td>0.018</td>
<td>0.081***</td>
<td>-0.016</td>
<td>0.020</td>
</tr>
<tr>
<td>cons</td>
<td>9.490</td>
<td>9.589</td>
<td>9.222</td>
<td></td>
</tr>
</tbody>
</table>

**Inefficiency covariates**

| ln of age of head                         | 1.998**     | 0.717               | 1.099**              | -0.121                   |
| ln of head education                      | 1.063**     | 0.521**             | 0.598                | -0.076                   |
| ln of household size                      | 0.454       | 0.372               | 4.693***             | 0.039                    |
| ln of extension contact                   | 0.068       | 0.008               | -1.769               | 0.031                    |
| ln of seminars attended                   | -0.129**    | -0.069**            | -0.930*              |                          |
| ownership of title (1,0)                  | -0.945***   | -0.327***           | -2.065***            |                          |
| credit access (1,0)                       | -26.275**   | -0.085*             | -26.894**            |                          |
| Grup membership (1,0)                     | -0.175**    | -0.271**            | -2.256**             |                          |
| ln of distance to market                  | 0.422***    | 0.221**             | 0.691                | -0.063                   |
| gender, if head is female (1,0)           | 0.386       | -0.072              | 2.601**              |                          |
| intercept                                 | -12.107     | -2.552              | -14.671              |                          |
| Sigma                                     | 0.934       | 0.745               | 0.869                |                          |

* = sig at 0.10, **=sig at 0.05, ***=sig at 0.01
5.0 CONCLUSION AND POLICY RECOMMENDATIONS

Constraints of production inefficiency among smallholder farmers in Kenya are ownership to farmland, attendance to agricultural workshops, access to credit and participation in self-help groups, which significantly reduce production inefficiency, while age, market distance, female gender and formal education increase inefficiency. With the available technologies, farmers can improve on their productivity if they nurture teamwork as in groups where labour is shared. Besides, better roads would reduce transaction costs and promote higher returns, and frequent agricultural workshops would boost efficient resources use for better performance if taken into consideration. Therefore, there exists opportunity to improve efficiency in production given existing farm technologies.

REFERENCES


