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An Analysis of Technical Efficiency of Rice Farmers in Ahero Irrigation Scheme, Kenya

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Abstract
Rice has continued to be an important cereal in Kenya in the recent years. Although it is third after maize and wheat in terms of consumption and production, its rate of consumption has increased over the years compared to maize and wheat. Rice production in Kenya does not meet demand, and the deficit has to be met with imports. Improving productivity would ensure increase in production, improved food security, reduced rice import bills and increased income among smallholder farmers. The current study, therefore, estimated technical efficiency of rice farmers in Ahero Irrigation Scheme, Kisumu County, Kenya. Stratified sampling and probability proportionate to size sampling was used to sample 220 rice farmers. A stochastic Cobb Douglas production function was used to estimate technical efficiency. The study further assessed the factors that affect technical efficiency of the rice farmers. The coefficients of fertilizer and labour were found to positively influence paddy productivity while that of chemical cost negatively influenced paddy productivity. The level of efficiency of rice farmers was found to be 0.82. The study further found that gender, farming experience, income level and distance to market were found to be significant determinants of technical efficiency. The study therefore recommended policies that will ensure that the costs of productive inputs are affordable to farmers and improving households' income through better prices for their outputs. Improvement in the transport infrastructure is also important in reducing inefficiencies in paddy production.
Key words: Rice, technical efficiency, stochastic Cobb Douglas production function, Kenya

1.0 Introduction

Cereals continue to play an important food security role in Kenya. Among this subsector, maize ranks first, followed by wheat and rice (Export Processing Zones Authority 2005, Republic of Kenya 2008, Kamau 2013). Although over the years there has been over dependence on maize as a food security crop in Kenya (Emongór *et al.* (2009); Chemonics International Inc. (2010)), during the two time periods of 2000-2004 and 2005-2009, maize consumption has declined by about 4%. During the same periods the consumption of rice has steadily increased by about 32% (Table 1). Moreover, according to the National Rice Development Strategy (NRDS 2008 – 2018) the annual rice consumption has been increasing at a rate of 12% compared to 4% and 1% for wheat and maize (Republic of Kenya, 2008).

Table 1: Consumption of major cereals in Kenya (kg/capita/year)

Commodity	Year 2000-2004	2005-2009	Difference between the two periods	Average	Percentage change
Rice	5.8	7.6	**1.8**	6.7	31.7
Sorghum	1.6	2.0	**0.3**	1.8	20.7
Millet	1.0	1.3	**0.3**	1.2	34.5
Wheat	25.3	25.4	**0.0**	25.4	0.2
Maize	83.4	79.8	**-3.6**	81.6	-4.4

Source: Computed from FAOSTAT 2013 data

Some authors attribute the increase in rice consumption vis-à-vis the other cereal staples to the changes in eating habits (Emongór *et al.,* 2009). The challenge, however, is that production has not kept pace with the increase in demand for rice. For instance, rice productivity declined from 42 bags per hectare in 2003 to 29 bags per hectare in 2007 (Emongór *et al.* 2009). The decline in production has been largely blamed on production inefficiencies (Kuria *et al.,* 2003; Kamau, 2013) and increase in demand. As a consequence of the decrease in productivity and increase in demand there is a huge deficit of about 75%-85% which is met by imports (Chemonics International Inc., 2010).

Reliance on the world market for supply of rice is also constrained. Gulati and Narayanan (2002), for example argue that the world rice market is still characterized by thinness, volatility, and segmentation. Despite the growing absolute volumes, trade constituted only about 4.5 percent of world rice production from 1961 to 2000, compared with 18 percent for wheat and 13.6 percent for maize (Gulati and Narayanan, 2003). This is partly attributable to the fact that much rice is consumed where it is produced and partly because of the nature of policies pertaining to rice sectors across the world. Moreover, importation of rice has a high opportunity costs as the funds are diverted from productive investment such as purchase of productive agricultural inputs including fertilizer as well as investment in infrastructure development. Increased investment in the rice sub-sector has a great potential to increase farm incomes, boost productivity, lower the price to consumers and increase food security in the country (Republic of Kenya, 2008).

In recognition of the important role of the rice subsector, the Government of Kenya developed and implemented the National Rice Development Strategy (NRSDS 2008 – 2018) in efforts to reverse the declining trends in rice production. The strategy emphasizes that rice is a source of cash and food security for small scale farmers, a view that is supported by several authors (Emongór *et al.,* 2009; Gitau *et al*., 2011). Gitau *et al*., (2011), for instance, argues that although the country meets only 20% of its rice consumption needs, there is need to shift from dependence on maize for food security to other cereals like rice and wheat.

About 20% of the rice produced in Kenya is from government established irrigation schemes (Mwea, Ahero, Bunyala and West Kano) while 20% is from under rain fed conditions (Republic of Kenya 2008). As envisioned in the NRDS (2008 – 2018), there is need to increase rice productivity hence increasing food production. Furthermore, rice is one of the crops identified to boost food security in Kenya, the other one being potato. The government of Kenya is also aiming at increasing the area under irrigation especially in schemes that majorly produce rice (Republic of Kenya, 2009). This will help in increasing farmers' incomes and enhancing food security, hence achieving the Millennium Development Goal (MDG) of eradicating extreme poverty and hunger.

Studies undertaken to assess the performance of the rice sub-sector emphasize technical inefficiencies as the main cause of declining productivity. Kuria (2003), for example argues that that farmer's failure to use the most efficient techniques might be due to non-physical inputs, such as socio-economic and institutional factors. In a study that assessed technical efficiency among smallholder farmers in Mwea irrigation scheme, Kuria *et al.* (2003) found that farmer's education level, farming experience, availability of credit and extension facilities influenced technical efficiency. Emongór *et al.* (2009) examined the rice value chain in Kenya with preference to producers. The authors argue that labour and capital are major constraints to rice production in the country. While previous studies point to the need to improve productivity by enhancing human capital, improving farmers' access to productive inputs, and increased investment in infrastructure, none to the best of our knowledge has examined the productivity of the productive inputs. Hence, this is an attempt to determine the productivity levels of rice farmers in Ahero irrigation scheme in Nyando District, Kisumu county, Kenya, and factors that determine their productivity levels. Such information will be useful in designing policies that target improving farmers' productivity, income and food security.

2.0 Materials and method

2.1 Study area

The study was conducted in Ahero Irrigation Scheme in Nyando District, Kisumu County, Kenya. The scheme is located in Kisumu County in the outskirts of Kisumu city. The climate of the area is relatively dry with high temperatures. The scheme is managed by the National Irrigation Board in partnership with the farmers who are charged Kshs.3100 per acre per year for scheme Operation and Maintenance (O&M). The area under cultivation is 2168 acres which is divided into 12 blocks with a total of 1650 farmers. Nearly all irrigated farmland is used for paddy cultivation.

2.3 The data

A household questionnaire was used to collect primary data from rice farmers in Ahero irrigation scheme, in the month of April 2012. A sampling frame which is a list of all the farmers in the various blocks was obtained from the Ahero regional office. Stratified sampling was performed using the 12 blocks as strata. 8 blocks out of the 12 blocks were then randomly selected. Probability proportionate to size sampling was then performed to give a sample of 220 farmers. Properly trained and carefully selected enumerators pre-tested the questionnaire and later collected data on input use, outputs and socioeconomic characteristics.

2.4 Empirical model

Variations in output by different producers, caused by technical inefficiencies can be captured through specification of a production function. Technical efficiencies can be estimated using Stochastic Frontier Approach (SFA) or Data Envelopment Analysis (DEA), which is a non-parametric approach. DEA assumes that there are no random effects in production. The current study therefore employed the stochastic production frontier approach because most farmers operate under uncertain conditions (Abedullah and Ahmad, 2006). Review of literature revealed that Cobb Douglas and Translog production functions are the widely used forms in agriculture. However, Translog production function specification suffers from multicollinearity problem as a result of the square and interaction terms of the inputs used (Hussain *et al*., 2012). The current study therefore estimated a Cobb Douglas production function, specified as:

$$Y_i = f(x_i, \beta) + v_i - u_i$$

Where Y_i is the output; x_i is a vector of inputs quantities used in production; β is a vector of parameters of the production function. The frontier production function $\{f(x_i, \beta)\}$ measures the maximum potential output from a vector of inputs. The error components v_i and u_i causes deviations from the frontier.

v_i is the systematic error component which captures random deviations from the frontier, caused by factors beyond the farmers' control such as temperature and natural hazards. It is assumed to be independently and identically distributed with a mean of zero and constant variance –N $(0, \sigma_v^2)$ and independent of u_i.

u_i is a non-negative error component that captures deviations from the frontier caused by controllable factors . It represents the inefficiencies in production. It is assumed to be half normal, identically and independently distributed with a mean of zero and constant variance-N $(0, \sigma^2)$.

Technical efficiency (TE) is defined in terms of the observed output relative to the production frontier, given the available technology, such that $0 \leq TE \leq 1$.

The production function can be log linearized to be:

$$lnY_i = \beta_0 + \sum_{k=1}^{4} \beta_k lnx_{ki} + v_i - u_i$$

Where Y_i is dry paddy in kg/acre;x_1 is seed in kg/acre;x_2 is fertilizer in kg/acre;x_3 is labour man-days/acre; x_4 is chemical costs in Kenya shillings/acre;β_0 is the intercept: β_k are the production function parameters to be estimated; v_i and u_i are as defined above.

Cobb-Douglas functional form is used in this study because the coefficients estimated directly represent elasticity of production (Abedullah and Ahmad, 2006). Cobb-Douglas production function is adequate in the representation of the production process since we are only interested in the efficiency measurement, and not production structure (Taylor and Shonkwiler, 1986). Furthermore, Cobb Douglas production function has been widely applied in estimating farm efficiencies (Ahmad *et al*., 1999; Kebede, 2001; Hassan and Ahmad, 2005; Abedullah and Ahmad, 2006; Ogundari and Ojo, 2007; Abedullah and Mushtaq, 2007; Oladeebo and Fajuyigbe, 2007; Narala and Zala, 2012; Hussain *et al*., 2012).

There is evidence that socioeconomic variables influence producers' efficiency, which will be included in the inefficiency model (Seyoum *et al*., 1998; Oladeebo and Fajuyigbe, 2007). The inefficiency effects model is specified as:

$$\mu_i = \gamma_0 + \gamma_k \sum_{k=1}^{9} z_{ki}$$

Where,

μ_i is farm specific inefficiency; γ_0 is the intercept; γ_k is the parameter of the k^{th} explanatory variable; z_1 is farming experience in years;z_2 is gender (1=male, 0=female); z_3 is number of years of formal education;z_4 is extension contacts in the year 2011(1=accessed extension services, 0=did not access extension service); z_5 is off farm income (1=earns off farm income, 0=do not earn off farm income); z_6 is distance to market (km); z_7 is income level 1 in Ksh./year(1=earns between 1-30,000, 0=otherwise); z_8 is income level 3 in Ksh./year(1=earns between 60,001-90,000, 0=otherwise); z_9 is income level 4 in Ksh./year(1=earns between 90,001-120,000, 0=otherwise)

The models were estimated using STATA version 10, using the maximum likelihood estimation method.

3.0 Results and discussion

Table 3: Descriptive statistics (N=221)

Age in years	
15-30	3.20
31-45	27.60
46-60	34.80
61-75	30.30
Above 75	4.10
Farming experience in years	
0-5	6.33
6-10	19.46
11-15	21.27
Above 15 years	52.94
Education level	
None	7.69
Primary education	61.09
Secondary education	28.05
College	2.26
University	0.90
Annual income category (Kenya shillings)	
1-30,000	3.62
30,001-60,000	18.55
60,001-90,000	49.77
90,001-120,000	22.17
120,001-150,000	5.88
Earned off farm income	39.37
Had access to extension services	76.47

Table 3 represents the descriptive statistics. Rice production in Ahero Irrigation Scheme, in Kenya is dominated by male farmers who comprised about 70% of the sampled farmers. Most farmers are in the 46-60 years category which was about 35% of the sample, with a mean of 54 years. This implies that rice farming is mainly practiced by older farmers. Consequently, about 53% of the sampled farmers have more than 15 years farming experience, with an average of 18 years. Most farmers, about 61% had completed only primary school education, with a mean of 7 years of formal education. About half of the sampled respondents earned 60,001-90,000Kshs annually, with a mean of Kshs 79,202. About 39% of the respondents earned off farm income while 76% had access to extension services with a mean of 1.86 contacts during the 2011/2012 season.

Table 4: Summary statistics of output, input and other variables

Variable	Mean	Std. error
Dry paddy (kg/acre)	2024.21	36.76
Fertilizer(kg/acre)	83.60	2.05
Seed(kg/acre)	25.25	0.21
Labour (man-days)	97.25	0.85
Chemicals cost (Kshs./acre)	494.07	23.23
Land size cultivated (acres)	3.23	1.23
Distance to market(km)	3.07	1.22

Source: computed from field survey data 2012

Rice farmers in Ahero Irrigation Scheme harvested about 2024kg per acre. Farmers applied on average 84kg and 25kg of fertilizer and seeds respectively per acre. The average labour used in rice production was 97 man-days per acre. Farmers in Ahero irrigation scheme spent about Kshs 494 on chemicals used in rice production to control diseases. The average land size under paddy was 3 acres while distance to market was about 3km (Table 4).

Table 5: Maximum likelihood estimates of the stochastic production function for rice production

Variable	Coefficient	Std. error	Z value
Fertilizer	0.085	0.050	1.68*
Seed	-0.118	0.137	-0.86
Labour (man-days)	0.430	0.141	3.04***
Chemical cost	-0.019	0.009	-2.18**
$Sigma^2$	61.308	137.501	
Gamma	0.999	0.001	
Mean technical efficiency	0.82		
H_0: No inefficiency component			-5.605***
Log likelihood	-23.331		
$Prob>chi^2$	0.0019		

Source: Computed from field survey data 2012 *,**,*** means significance at 10%, 5% and 1% level

Table 5 represents the results of the MLE of the Cobb Douglas production function. The null hypothesis that there is no inefficiency was rejected at 1% level of significance, indicating that there were inefficiencies in rice production. The Wald statistic was significant at 1% level of significance indicating that the variables included fits the model appropriately. The Gamma variable shows that about 99.9% of variations in productivities among farmers is caused by farmer specific inefficiencies. This is particularly true for Ahero irrigation scheme because the physical conditions such as weather conditions and soil characteristics are similar.

Three of the four variables are significant. Fertilizer and labour coefficients are positive and significant while chemical cost coefficient is negative and significant. This implies that increase in fertilizer and labour would increase the output while increase in chemical costs reduces rice productivity. The mean technical efficiency of 0.82 shows that productivity can be increased by 18% if the inefficiencies are eliminated, using the same input levels.

Table 6: Elasticity of production and returns to scale

Variable	Elasticity
Fertilizer	0.085
Seed	-0.118
Labour (man-days)	0.430
Chemicals cost	-0.019
Returns to scale	0.378

Source: Computed from field survey data 2012

The estimated coefficients of a Cobb Douglas production function can be directly interpreted as elasticities of production. Labour has the highest elasticity of production of 0.43 followed by fertilizer (Table 6). This implies that a 10 percent increase in man- days and fertilizer will lead to a 4.3 percent and 0.8 percent increase in dry paddy respectively. However, increase in seed quantity and chemical cost reduces the output. The value of Returns to scale of 0.35 indicates that rice farmers are operating in a decreasing returns to scale stage.

Table7: Efficiency score distribution (N=220)

Efficiency score range	Percentage
0.20-0.30	0.5
0.31-0.40	1.4
0.41-0.50	2.7
0.51-0.60	2.7
0.61-0.70	7.7
0.71-0.80	15.9
0.81-0.90	48.2
Above 0.90	20.9
Maximum TE	0.95
Minimum TE	0.30
Mean TE	0.82

Source: Computed from field survey data 2012

The estimated farm specific technical efficiency ranged between 0.30 and 0.95 with a mean of 0.82 (Table 7). It is observed that about 31% of the sampled farmers operate below the mean efficiency score of 0.82. However, about 21% of the farmers operate above 0.90 level of technical efficiency. The mean efficiency score of 0.82 indicates that in the short run rice productivity can be increased by 18% through reduction of inefficiencies.

Table 8: Inefficiency effects model

Variable	Coefficient	Std. error	t value
Gender	-0.050	0.18	-2.79***
Education level	-0.007	0.128	-0.57
Farming experience	-0.002	0.001	-1.98**
Extension contact	-0.010	0.019	-0.55
Off farm income	0.018	0.017	1.05
Income level 1 (1-30,000)	0.137	0.044	3.11***
Income level 3 (60,001-90,00)	-0.074	0.022	-3.41***
Income level 4 (90,001-120,000)	-0.091	0.025	-3.69***
Distance to market	0.007	0.004	1.68*
Constant	0.311	0.037	8.33***

Source: Computed from field survey data 2012

Table 8 represents the results of technical inefficiency effects model. The coefficients of farming experience, income levels and distance to market had the expected priori signs and were significant in determining farmers' efficiency in rice production. Farmers with more experience are more efficient than farmers with less experience in farming. Experience helps farmers in using farming techniques that reduce the inefficiencies. Similar findings were reported by Kuria *et al*. (2003), Abedullah and Ahmad (2006), Kinkingninhoun-Meˆdagbe´ (2010), Narala and Zala (2010), and Maganga (2012). As the income levels of the farmers increased, so did their efficiency. Farmers who earned income in level 1 (Ksh1-30,000) had lower efficiency compared to those in income levels 2 (Ksh60,001-90,000) and 3 (90,001-120,000). Income is a proxy for wealth, implying that wealthy farmers can afford expensive farming inputs which improves their productivity. Ojo (2012) used farm income which was positively related with efficiency, although was found to be insignificant. Distance to market is positively related with inefficiency, implying that as distance increases, the inefficiencies in production also increase. The gender variable is also significant in determining farmers' efficiency. Male rice farmers were found to be more efficient compared to their female counterparts.

Education level, extension contact and off farm income have the expected signs although not significant. Increase in education level reduces the inefficiencies in rice farming. This is consistent with findings of Kuria *et al*. 2003, Abedullah and Ahmad (2006), Abedullah *et al.* (2007), Maganga (2012) and Ojo (2012). Contact with extension worker reduces the inefficiencies as expected. Off farm income on the other hand increases the inefficiencies rice production. Rice farming is a labour intensive enterprise hence involvement in off farm activities reduces the time devoted to farming. Similar findings were reported by Maganga (2012).

4.0 Conclusion and policy implications

The study has revealed that rice farmers in Ahero irrigation Scheme are not fully technically efficient in using the productive resources. The results of Cobb Douglas production function shows that increase in fertilizer and labour in rice farming could increase its productivity. On the other hand, seed and chemical cost reduces rice productivity. Policies should therefore aim at reducing the cost of productive inputs such as fertilizer and chemicals in order to enable farmers increase their usage.

Farming experience, gender, income level and distance to market were found to be important determinants of technical efficiency. Policies should therefore target improving transport infrastructure in the region to improve on efficiency. This will improve market access for both produce and inputs. Rural households' incomes should also be improved, which improves on adoption of agricultural technologies. This can be achieved by improving productivity through use of improved technologies such as high-yielding varieties and fertilizer, improving market access, and reducing postharvest losses.

Improving farmers' efficiency in rice production therefore has a potential of increasing rice production in the country. This in turn will have direct effects of increased output, hence food security, increased income among the farmers and reduction of the supply demand gap which will reduce rice import bill to be used in other development initiatives.

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