Research Journal of Agriculture and Environmental Management. Vol. 3(8), pp. 380-392, August, 2014
Available online at http://www.apexjournal.org
ISSN 2315 - 8719© 2014 Apex Journal International

Full Length Research

Technical Efficiency of Farming Households in Uganda: Evidence from the national Panel Survey Data, 2005-2010

Rebecca M. Kalibwani[1]*, John Mutenyo[2] and Edward Kato[3]

[1]Department of Agriculture and Agribusiness, Bishop Stuart University, Mbarara, Uganda.
[2]College of Business and Management Science, Makerere, University, Kampala, Uganda.
[3]International Food Policy Research Institute (IFPRI), Washington, USA.

Accepted 14 July, 2014

We investigate performance of the agricultural sector in Uganda and whether it has varied by the 4 major regions in Uganda using agricultural technical efficiency as a proxy for performance on a nationally representative panel data set. We apply the classical parametric stochastic production frontier estimator in estimating the technical efficiency scores for each of the 4 regions using a panel framework. We find rather surprising results contrary to our hypothetical expectations. The households in the northern and eastern regions are found to have relatively higher levels of technical efficiency over the study period compared to the rest of the regions. The presence of increased government intervention in the peace process, and concerted effort by both government and international agencies to develop and promote agriculture programs in the region during this period, were possibly responsible for the observed levels and trends in technical efficiency in the two regions. The western region had the lowest levels of technical efficiency and a declining trend over the study period. Overall in the country data, male household heads are found to be more efficient than their female counterparts and the difference is found to be significant at 5%. Higher levels of education are found to significantly decrease inefficiency at the 10% level.

Key words: Technical efficiency, Stochastic Frontier Production function, inefficiency effects.

INTRODUCTION

Agriculture is a strategic sector in Uganda's economy, targeted for the transformation of the economy from a peasant to a modern prosperous society in 30 years (GoU, 2010). It plays a dominant role in export earnings where over 90% of exports of goods are agricultural products. It employs the largest proportion of Uganda's labour force providing a livelihood to about 86% of the population, and employment to about 77% of the labour force living in rural areas (MFPED, 2008, NIMES, 2007). The performance of the sector is therefore an issue of great policy concern (MFPED, 2008) where the major concern relates to overall agricultural productivity. Over the years 1987 to 2005, agriculture in Uganda performed well, growing at an average 3.8 percent, faster than population growth at that time. The sector was thus a major contributor to the success of Uganda's poverty reduction efforts in the 1990s (GoU, 2010). Relative to other countries in the region and worldwide, Uganda's long term agricultural growth trend was impressive. This long and sustained period of growth earned Uganda the distinction of being one of the most successful countries in terms of achieving high rates of poverty reduction. It also demonstrated the success of the policy framework adopted and maintained by Uganda - a conducive macro-economic policy environment and clear progress with

*Corresponding author. rmkalibwani@yahoo.com rmkalibwani@as.bsu.ac.ug

stabilization and market liberalization (GoU, 2010).

The main explanation for the increase in crop output over the years was an increase in the total area cultivated (UBOS, 2009, 2010). However, the World Bank analysis makes it clear that 'continued reliance on extensification of agriculture as a source of growth is likely to be environmentally disastrous and lead to enormous conflicts with diminishing grasslands and other areas for cattle grazing for the pastoralists. This implies that future growth will have to rely on a combination of more intensive agriculture among other things. However, real growth in agricultural output declined from 7.9 percent in 2000/01 to 0.1 percent in 2006/07 (UBOS, 2009), before recovering to 1.3 percent and 2.6 percent in 2007/08 and 2008/09, respectively. This rate of growth was below the population growth rate of 3.2 percent, implying that per capita agricultural GDP was declining at the time. It was also far short of the 6 percent growth target for the agricultural sector set by African Governments under CAADP**.** Given that 73 percent of all households in Uganda are engaged in agriculture, declining performance matters greatly for their livelihoods and represents a setback in the drive to eradicate poverty and create wealth (GoU, 2010).

Agriculture in Uganda consists mainly of farming in cash crops, food crops and livestock. The major food crops include bananas (*matooke*), maize, beans, millet, cassava, potatoes, sorghum while livestock production mainly consists of cattle and small animals such as sheep, goats, pigs and poultry. The major cash crops traditionally include coffee, cotton, tea and tobacco while the new commercial crops include vanilla, flowers and cocoa. The birds commonly reared as poultry include chicken, turkeys, ducks, geese and other birds (MFPED, 2008). This study concentrates on the major food crops in each region. Although there is clear indication that increased access and adoption of improved technologies has contributed to increased productivity, production per acre still falls below potential. When farm yields are compared with research stations figures, the yield gap (proportion of the difference between the two yield figures to research station yields) is glaringly big, which leaves a lot of room for improvement (PMA, 2007; GoU, 2010). Growth in production efficiency of the agriculture sector, and particularly small-holder agriculture, is recognized to be one major way that will contribute to the process of economic growth in developing countries.

Despite numerous policy reforms undertaken in the sector in the recent past and donor development assistance that has been invested in increasing productivity at the household level, poverty in the rural agricultural dependent households has risen which poses a challenge on how to continue to address this cardinal problem through agricultural intensification and extensification. Evidence is therefore needed on the past performance of the sector highlighting what factors have led to favourable positive impacts and those that have led to under-performance in agricultural productivity. The main objective of this study was therefore to quanti-tatively determine the level of technical efficiency of the farmers across the four regions of the country; central, eastern, northern and western, and the factors influencing efficiency, using the stochastic frontier production function. The technical efficiency of an individual firm can be defined in terms of the ratio of the observed output to the corresponding frontier output, conditional on the levels of inputs used by that firm. Technical efficiencies lie between zero and unity, where unity indicates that this firm is technically efficient (Piesse and Thirtle, 2000). Using two panel data sets collected by UBOS and representative of the heterogeneity in the country, the study provides micro econometric based evidence of sector performance during 2005-2010. Past studies have been limited both in scope and representativeness. This is also the first study to use the national panel data in assessing technical efficiency, while past studies mainly used cross sectional data (Obwona, 2002; Bagamba et al., 2004; Hyuha et al., 2007; Asiimwe, 2008).

MATERIALS AND METHODS

The Data

The study utilizes the Uganda National Panel Survey (UNPS) data sets of the years 2005/06, and 2009/10 collected by the Uganda Bureau of Statistics (UBOS). This national data is collected at household and community levels for two cropping seasons in each year. The two cropping seasons in the two years constitute four time periods for this study (i.e season 1 05/06, season 2, 05/06, season 1 09/10 and season 2, 09/10 are time periods 1, 2, 3, and 4 respectively). The data for this study was collected from two of the five modules of the UNHS; agriculture, and socio-economic modules. The data that was obtained for this study was on the various food crops cultivated in the four regions. Data was collected on area under the crops, the quantity harvested, whether households used organic, inorganic fertilizer, pesticides local or improved seed, and labour used whether family and/or hired labour. The data collected from the socio-economic module include farmer characteristics such as age, gender, education level, and information obtained by household on production.

Study area and Sample

The study covers the four regions of the country from which the data was collected ie central, eastern, northern and western. The sample for this study consists of 364

Table 1. Sample size and Districts represented in the Study.

Region	Sample size	Number of Districts
Central	98	16
Eastern	98	16
Northern	108	16
Western	60	11
Uganda (Total)	364	59

households drawn from initial sample of the UNPS of 3,220 that was visited both in 2005/06 and 2009/10 surveys. The sample households for this study were drawn from 59 of the 87 districts that were represented in the UNPS in the two periods. Table 1 shows the sample size in each region and the number of districts represented.

Estimation Methods

The stochastic frontier production function methodology is used to describe the production of the Ugandan farming households using the linearised Cobb-Douglas production frontier model. The estimation of technical efficiency follows specifically the model proposed by Battese and Coelli (1995) for panel data which assumes the presence of technical inefficiency in production. Battese and Coelli (1995) define a stochastic frontier production function for panel data on firms, in which the non-negative technical inefficiency effects are assumed to be a function of firm specific variables and time. The inefficiency effects are assumed to be independently distributed as truncations of normal distributions with constant variance, but with means which are a linear function of observable variables. The model proposed by Battese and Coelli (1995) for panel data is defined by;

$$Y_{it} = \exp(x_{it}\beta + v_{it} - u_{it}) \quad \text{.................................(1)}$$

Where Y_{it} denotes production at the *t-th* observation (*t = 1, 2, 3…..T*) of the *i-th* firm (*i = 1, 2, 3….N)* x_{it} is a *(1 x k)* vector of values of known functions of inputs of production and other explanatory variables associated with the *i-th* firm at the *t-th* observation,

β is a *(k x 1)* vector of unknown parameters to be estimated,

v_{it} these are assumed to be *iid* $N(0, \sigma_v^2)$ random errors, independently distributed of the $u_{it}s$. The u_{it}s are non-negative random variables, associated with technical inefficiency of production, which are assumed to be independently distributed, such that u_{it} is obtained by truncation (at zero) of the normal distribution with mean, $z_{it}\delta$ and variance, σ^2,

z_{it} is a (1 x m) vector of explanatory variables associated with technical inefficiency of production of firms over time, and

δ is an (m x 1) vector of unknown coefficients.

The technical inefficiency effects, the u_{it}s are assumed to be a function of a set of explanatory variables, the z_{it}s and an unknown vector of coefficients, δ. The technical inefficiency effect, u_{it}, in the stochastic frontier model (1) above is therefore specified as follows;

$$u_{it} = z_{it}\delta + W_{it} \quad \text{..(2)}$$

Where the random variable, W_{it} is defined by the truncation of the normal distribution with zero mean and variance, σ^2, such that the point of truncation is $-z_{it}\delta$.

Following the specification by Battese and Coelli (1995) above, the stochastic frontier production function model that is specified for the Ugandan small holder farming households is defined below;

$$\ln(Y_{it}) = \beta_0 + \beta_1(org)_{it} + \beta_2(Inorg)_{it} + \beta_3(pest)_{it} + \beta_4 \ln(croparea)_{it} + \beta_5(Hlab)_{it} + \beta_6(Flab)_{it} + \beta_7(Year_{it}) + v_{it} - u_{it} \quad \text{..............................} \quad (3)$$

Where In represents the natural logarithm (i.e to the base *e*),

Y_{it} represents the total value of output from the various food crops harvested by the *i-th* farmer at the *t-th* observation, and measured in kilograms,

org represents a dummy of the response on whether the household used organic fertilizer or not, so that *org*=1 if yes, and *org*=0 if otherwise,

$Inorg$ represents a dummy of the response on whether the household used inorganic fertilizer or not, so that

inorg=1 if yes, and *inorg*=0 if otherwise,
pest represents a dummy of the response on whether the household used pesticides, herbicides, and other chemicals, or not, so that *pest*=1 if yes, and *pest*=0 if otherwise,
croparea represents the total area in acres under the food crops harvested,
Hlab represents number of person days of hired labour,
Flab represents number of person days of family labour,
Year represents the time period of the observation (expressed in terms of 1, 2, 3, 4)
$\beta_0 ......\beta_7$ are unknown parameters to be estimated,
Assuming that the intercept β_0 varies across regions and not across time and individual households, the model is run separately for the four different regions, as well as the country data, giving five different sets of results.
v_{it} and u_{it} are as explained in (1) above, so that;

$$u_{it} = \delta_0 + \delta_1 age_{it} + \delta_2 sex_{it} + \delta_3 year_{it} + \delta_4 educlevel_{it} + \delta_5 \inf oprod_{it} + \delta_6 seedtype_{it} + \delta_7 \ln(croparea)_{it} \quad ...(4)$$

Where *age* represents the age of the household head measured in years,
sex represents the sex of the household head, (dummy so that male=1, otherwise=0)
year represents the time period of observation (i.e 1, 2, 3, 4)
educlevel represents the level of education of the household head (dummy),
infoprod represents the response on whether the household received information on production during the particular time period (dummy so that if yes=1, otherwise=0),
seedtype represents the response on whether the household used local or improved seed during the particular time period (dummy so that if yes=1, otherwise=0),
croparea represents the total area in acres under the food crops harvested,
$\delta_0 ....\delta_7$ are unknown parameters to be estimated. Similar to the stochastic production frontier model in (3) above, the inefficiency effects model in (4) is run for each region and for the country data, and simultaneously with the respective stochastic production frontier model.

Other variables that would possibly contribute to the technical efficiency of a household in production such as access to credit, membership in NAADS program or farmers' group and others were not captured by the panel data and hence could not be included in the model. The method of maximum likelihood is used for the simultaneous estimation of the parameters of the stochastic frontier and the model for the technical inefficiency effects. The parameters are estimated using the *Model 2 option* of the FRONTIER 4.1 program (Coelli, 1996) which is associated with the Battese and Coelli, 1995 model. The likelihood function is expressed in terms of the variance parameters, σ_s^2, and γ such that;

$$\sigma_s^2 = \sigma_v^2 + \sigma^2 \quad ....(5)$$

$$\text{And } \gamma = \frac{\sigma^2}{\sigma_s^2} \quad ....(6)$$

The γ parameter has a value between zero and one.
The prediction of technical efficiencies is based on its conditional expectation, given the model assumptions. The technical efficiency of production for the *i-th* firm at the *t-th* observation is defined as follows;

$$TE_{it} = \exp(-u_{it}) = \exp(-z_{it}\delta - W_{it}) \ ....(7)$$

Where u_{it}, z_{it}, δ and W_{it} are as explained above. The technical efficiency of a household lies between zero and one and is inversely related to the inefficiency effect. The efficiencies are predicted using the predictor that is based on the conditional expectation of $\exp(-u_{it})$ which is programmed in FRONTIER Version 4.1.

Hypothesis Testing

Several tests of hypothesis are performed using the generalised likelihood-ratio test statistic, λ defined by;

$$\lambda = -2\ln[L(H_0)/L(H_1)] \qquad ....(8)$$

Where $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. If the null hypothesis is true, the test statistic has approximately a chi-square or a mixed chi-square distribution with degrees of freedom equal to the number of restrictions in the null hypothesis (Gujarati, 2004).

RESULTS

Socioeconomic Characteristics of the Farming Households

The average age across the four regions was 38.67

Table 2. Selected Socioeconomic Characteristics of the Household heads.

Variable	Region				
Farmer Characteristics	**Central**	**Eastern**	**Northern**	**Western**	**Uganda**
Age (years)	37.80	38.47	39.23	39.40	38.67
Sex (dummy)	50.76	50.00	53.01	52.08	51.37
Educ (dummy)					
Primary	55.97	73.96	72.35	79.55	68.89
Secondary	28.81	19.31	16.59	14.39	20.65
Tertiary	15.23	6.93	11.06	6.06	10.45
Infoprod (dummy)	6.38	8.16	10.41	6.66	8.10

Source: Author's calculations from study sample

Table 3. Commonly grown food crops per region.

Region	Common food crops
Central	Bananas (all types), Maize, beans, cassava, sweet potatoes
Eastern	Fingermillet, cassava, rice, cowpeas, soya bean, sweet potatoes.
Northern	Simsim, sorghum, field peas, pigeon peas, soya bean, groundnuts.
Western	Bananas (all types), Irish potatoes, beans, finger millet.
Uganda	Bananas (food type), maize, beans, cassava, sweet potatoes.

Source: UBOS, 2011

years. Household head age range in the study sample was well within the expected range of the working age population for Uganda (26-49 years) as well as the age range for household heads participating in agriculture (36-40 years) as observed in UBOS, 2010. The study sample nearly had as men as women household heads, as represented by the percentage of men which about 50% for all regions and the country sample (Table 2).

Education level of the household head was categorized into three, depending on the highest level of schooling attained; primary, secondary and tertiary. 80% of the household heads in the four regions, were found to have attained at most secondary school education. This compares well with the 76.9% reported by UBOS 2011a to have attained at most secondary school education. UBOS 2010 reports that the literacy rate in the country increased from 69-73% between 2005 and 2010 which was also the study period. This is promising for the transformation of agriculture in the country since better educated farmers are believed to be more commercialized, and better adopters of technologies. The effect of schooling years on agriculture was found to be positive and significant by World Bank, 2011 up till the advanced years of secondary school. Households that reported having received information on production from sources such as an NGO, input dealer, processor and NAADs, were scanty. The highest percentage of households was found in the northern region with 10.41% while the sample average was 8.10%. However, the UNPS data for this period 2005-2010 does not capture the households that were involved in NAADS activities, although this would have been useful for the study.

The crop area captured most was that of the most commonly grown food crops for each region as shown in Table 3. The households raise various enterprises as with the traditional methods of farming, including among others Bananas, Maize, Beans and Cassava, as the most widely grown crops by the farming households in Uganda (UBOS, 2007). The households in the sample were mostly small scale farming households as noted by World Bank 2011 that Uganda is dominated by small scale farms of up to 1 ha, on average 0.7ha (1.75 acres) (World Bank, 2011).

The respondents were asked to estimate what was harvested (post-harvest estimates) during the last completed, crop-by-crop, in measurement units that they

Table 4. Model Specification.

Null Hypothesis	Test statistic, λ	Critical Value at 5% χ^2	Decision
$H_0; \beta_{jk} = 0, j \leq k = 1,2.......22$	13.8	33.92	Accept H_0

were familiar with. Using a conversion factor for each measurement unit, the units were converted to kilograms. The total value of the output produced by a given household was obtained by multiplying the number of kilograms of the different crops by respective prices.

Generalised Likelihood-ratio Tests of the Null Hypotheses

In order to test the appropriateness of the model specified in (3) tests of hypothesis were performed to select between the Cobb-Douglas and the more flexible translog specifications.
The following null hypothesis was tested;

1. $H_0; \beta_{jk} = 0 \quad j \leq k = 1,2,..........22$ specifies that the Cobb-Douglas frontier model is an adequate representation of the data. The Cobb-Douglas functional form is a restricted form of the translog model in which the second-order terms in the model are restricted to be zero. If the hypothesis is true, the model becomes an ordinary linear model. The results are shown in Table 4.

The other hypotheses tested concerned the coefficients of the technical inefficiency effects across the four regions as follows.

2. $H_0; \gamma = \delta_0 = \delta_1 = ...\delta_7 = 0$ specifies that the inefficiency effects are not important in describing the variations in output of the farming households.
3. $H_0; \delta_1 = \delta_2 = ...\delta_7 = 0$ This null hypothesis specifies that the coefficients of the explanatory variables in the inefficiency effects model are zero. The inefficiency effects are not significantly influenced by the selected variables.

Given the results in the Table 4, the first hypothesis cannot be rejected at the 5% level of significance implying that the linearised application of a Cobb-Douglas production function is the one that best fits the data. The second-order terms which also spell out interactions among the inputs are not important in describing variations in output.

Having selected the preferred functional specification, it is also important to test for the presence of inefficiency effects in the data. The second hypothesis that the inefficiency effects are not important in describing variations in output cannot be rejected at the 5% level of significance for country data, implying that the inefficiency effects are not that significant in explaining variations in output production of the households in the country sample. However there are differences among regions.

The third hypothesis that the coefficients of the explanatory variables in the inefficiency effects model are zero is rejected at the 5% level of significance except for the northern region. This implies that the selected variables do influence the level of technical efficiency of the farming households in the rest of the samples during the study period. The results of the two hypotheses are shown in Table 5.

The maximum likelihood estimates of the parameters of the stochastic frontier and the inefficiency effects models are shown in Table 6 below. The coefficient of the intercept is significant in the four regions and in the country sample. This indicates that households that used minimal quantities of the selected inputs and where possible none at all, achieved on average significantly more output than households that used the inputs. Significant output can be obtained in all the four regions, with minimal effort on the part of farming household. This is to be expected since the soils and climatic conditions in the country as a whole, in spite of regional differences, do favor crop production. Households using organic fertilizer in the eastern region were found to obtain 80% less output than those who did not, a finding that was significant at 1% level. The country data shows that an extra person day of hired and family labour resulted in a reduction in the level of output of 9.7% and 3.6% respectively, both significant at the 1% level. In the country sample, holding all other factors constant, those who did not use the inputs got on average 2.7% more output that those who did, and the finding was significant at 1%. On the whole the results indicate that in the prevailing circumstances there was over use of the inputs; the use of the inputs resulted in lower levels of output than should actually be the case. The circumstances varied across the regions during the study

Table 5. Tests of Hypotheses for the coefficients of the explanatory variables of the technical inefficiency effects in the stochastic frontier production function of the four regions.

Null Hypothesis	Log-likelihood Value	Test Statistic, λ	Critical Value χ^2	Decision
$H_0;\gamma=\delta_0=\delta_1=......=\delta_7=0$				
Central	-709.83	16.8	15.5	Reject
Eastern	-741.17	10.18	15.5	Accept
Northern	-825.99	3.68	15.5	Accept
Western	-418.51	16.36	15.5	Reject
Uganda	-2707.6	6	15.5	Accept
$H_0;\delta_1=\delta_2=\delta_3=\delta_4=\delta_5=\delta_6=\delta_7$				
Central	-709.83	16.8	14.06	Reject
Eastern	-719.00	34.08	14.06	Reject
Northern	-825.99	3.68	14.06	Accept
Western	-418	16.36	14.06	Reject
Uganda	-2610.7	187.8	14.06	Reject

period. Among those reported in literature are the poor adoption of improved inputs (Kasirye, 2013), unfavorable prices of both inputs and food crops (MFPED, 2010a) and natural hazards such as floods in the eastern region (NEMA, 2010) among others. The technical efficiency of the households similarly varied across the regions as discussed.

Technical efficiency across the regions: The technical efficiency scores of the individual households are generated by the FRONTIER 4.1 program simultaneously with the parameters of the stochastic and the inefficiency effects model. The mean technical efficiency scores of the four regions in each of the time periods of the study were obtained from the individual household scores and are shown in Table 7. For three regions; the central, eastern, and northern regions, the technical efficiency scores rise from a low of 0.169 in the central region in time period 1, to a maximum of 0.959 in the northern region in time period 4. The reverse is true in western region where technical efficiency scores are found to decline throughout the study period from a mean of 0.578 in time period 1 to 0.176 in time period 4. The technical efficiency of the farming households was lowest in the second season of 2005, time period 1, where the overall mean for the country data is 0.582 and highest in the first season of 2010, time period 4, at 0.781. Table 8 summarises the mean TE scores of the regions in the four time periods and these trends are further shown in Figure 1.

Overall, the study findings reveal that the technical efficiency of 51.4% of Ugandan farming households lies above 70% as shown by the frequency distribution in Table 9. This means that an average farming household produced 70% of the maximum attainable output for given input levels over the study period. All the households sampled from the northern region are found within this range representing 58% of the total sample while 42% of those above 70% were found in the eastern region. Households sampled from the central and western regions representing 43% of the households in the overall sample constituted the households technical efficiency below 70%. The two regions experienced the lowest levels of household technical efficiency during the study period.

The mean TE score for the entire study period is highest for the northern region at 0.936 and lowest for the western region at 0.367 (Table 8). The eastern region follows the northern with 0.755 followed by the central region with 0.464. The wide range in mean technical efficiency from 36.7% to 93.6% indicates that opportunity exists for households to raise their productivity given appropriate environment. The four regions experienced situations specific to each region during the study period which could have impacted differently on productivity and hence technical efficiency in the respective regions. These are further discussed.

The northern and north-eastern districts of Uganda were affected by two decades of insurgency due to conflicts led by the Lord's Resistance Army (LRA) from

Table 6. Maximum Likelihood Estimates for the Parameters of the Stochastic Frontier and Inefficiencies Model in the four Regions.

Variable	Region									
	Central		Eastern		Northern		Western		Uganda	
	Coeff	t-ratio	coeff	t-ratio	Coeff	t-ratio	coeff	t-ratio	coeff	t-ratio
Stochastic Frontier										
Constant	4.66***	5.04	2.89*	1.73	2.18***	8.49	2.28***	4.47	2.35***	7.12
Organic fertiliser	0.18	0.57	-0.80***	-5.58	0.24	0.29	-0.38	-1.21	-0.15	-0.18
Inorganic fertiliser	-0.44	-0.68	0.46	0.94	-0.53	-0.65	-0.15	-0.38	-0.24	-0.25
Chemicals	-0.01	0.02	0.2	0.53	-0.008	-0.01	-0.54	-1.32	0.04	0.04
Crop area	-0.12	-1.46	-0.08	-0.38	0.02	0.54	-0.25	-2.26	0.0006	0.007
Hired labour	-0.006	-0.68	-0.01	-1.19	-0.01	-1.09	-0.009	-0.92	-0.09***	-3.36
family labour	0.0003	1.07	-0.0004	-0.69	0.003	0.2	-0.002	-1.49	-0.09*	-1.58
Inefficiency Model										
Constant	2.78**	2.3	1.35	0.85	-0.19**	-2.33	-0.66	-0.63	-0.02	-0.03
Age	0.005	0.74	0.01	0.38	0.008***	4.32	-0.01	-1.48	0.006	0.59
Sex	-0.21	-0.86	-0.71	-0.44	-0.22**	-1.91	0.45	1.61	-0.21**	-2.01
Year	-0.68*	-1.81	-0.43	-0.75	-0.03***	-3.5	0.83***	2.55	0.22	1.32
Education	0.16***	-2.7	-0.30	-0.29	-0.06***	-6.87	0.18**	2.18	-0.11	-1.67
Infoprod	0.29	1.09	-0.75	-0.09	0.03	0.2	-0.08	-0.17	0.09	0.12
Seed type	-0.23	-0.53	0.39	0.94	0.09	0.56	-0.43	-0.62	0.19	1.01
Crop area	-0.05	-0.54	-0.22	-0.79	0.06	1.35	-0.34	-1.67	0.06	0.33
Gamma	0.003	0.1	0.05	0.53	0.0008*	1.9	0.33	1.3	0.004	0.87
Log-likelihood function	-701.4		-736.1		-824.1		-410.4		-2704.6	

***Significant at 1% level, **Significant at 5% level, * significant at 10% level

1986 and cattle rustling by Karimojong warriors. As a result of the economic stagnation arising out of the insurgencies, the Government of Uganda instituted a number of development interventions such as the Northern Uganda Social Action Fund (NUSAF), a five year community driven project which was implemented between 2003-09. The GoU also started the development of a Peace, Recovery and Development Plan (PRDP) in 2006, as a new commitment to stabilise and recover the North through a set of coherent programmes, focussing on production, and natural resources management among other things. The NUSAF project is said to have made significant progress in building capacities of communities particularly in agricultural production (EU, 2007). According to EU 2007, the Lango sub-region consisting of Lira, Amolatar, Dokolo, Apac and Oyam districts had more intense agricultural activities attributed in part to the early resettlement of the population and the existence of development projects in the

Table 7. Mean Technical Efficiency Scores of the Four Regions.

Region	Time Period	Mean TE	Standard Deviation	Min.	Max.	Range
Central	1	0.169	0.073	0.077	0.387	0.309
	2	0.298	0.106	0.132	0.727	0.594
	3	0.525	0.178	0.197	0.969	0.771
	4	0.864	0.129	0.518	1	0.481
Eastern	1	0.63	0.203	0.169	0.935	0.766
	2	0.689	0.193	0.294	0.951	0.657
	3	0.828	0.11	0.491	0.952	0.461
	4	0.871	0.084	0.375	1	0.624
Northern	1	0.914	0.107	0.522	1	0.478
	2	0.936	0.096	0.559	1	0.441
	3	0.936	0.104	0.521	1	0.479
	4	0.959	0.062	0.68	1	0.32
Western	1	0.578	0.112	0.32	0.799	0.478
	2	0.443	0.172	0.147	0.813	0.666
	3	0.273	0.179	0.047	0.698	0.65
	4	0.176	0.158	0.037	0.585	0.548
Uganda	1	0.582	0.312	0.078	1	0.922
	2	0.617	0.291	0.132	1	0.868
	3	0.687	0.281	0.047	1	0.953
	4	0.781	0.293	0.037	1	0.962

Table 8. Summary of the Mean TE scores between 05/06-09/10.

	Time Period				
Region	1	2	3	4	Mean TE
Central	0.169	0.298	0.525	0.864	0.464
Eastern	0.63	0.689	0.828	0.871	0.755
Northern	0.914	0.936	0.936	0.959	0.936
Western	0.578	0.443	0.273	0.176	0.367
Uganda	0.582	0.617	0.687	0.781	0.885

area. These are districts that were included in the study sample for the northern region and this could explain the relatively higher levels of technical efficiency for the region during the study period. On the contrary, UBOS 2007 indicates that poverty levels in northern Uganda at 61%, nearly twice the national level of 31%. The poverty levels in northern Uganda could be explained partly by the low food crop price levels and the lack of market access that prevailed during the study period (MFPED, 2010b) among other circumstances specific to the region. None the less, the findings indicate that small holder farmers in the north are poor but efficient.

The NUSAF interventions spread to the north-eastern parts of the country, in the eastern region, neighbouring the northern region. The Teso sub-region in particular including districts such as Katakwi, Soroti, Kumi was affected by cattle rustling and therefore covered by the NUSAF project. The results of this study indicate that the

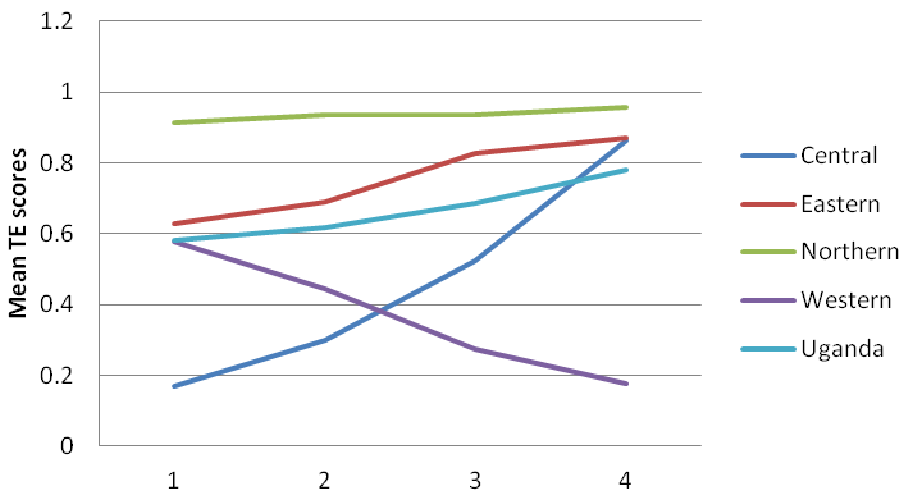

Figure 1. Mean Regional TE scores between 05/06-09/10.

eastern region follows the northern region with relatively higher levels of technical efficiency in the study period. The targeted interventions for these regions during this period might be responsible for maintaining the levels of productivity and technical efficiency of the households that participated in agriculture.

The western region of Uganda consists of districts in the south-western part of the country such as Ntungamo, Mbarara, Bushenyi and Kabale among other as well as the western districts such as Masindi, Hoima and Fort Portal. The southwest of the country was identified as one of the key land degradation hotspots where soil erosion and infertility were rampant (NEMA 2010). The same area is situated in the so called cattle corridor where sustainable land management is threatened by overgrazing by local and mobile pastoralist herds, deforestation by excessive use of fuel wood resources and poor and inappropriate agriculture on marginal land (NEMA 2010). The declining levels of productivity for the western region could be explained by the increasing levels of land degradation in the region during this period. The western region was reported to be the best performing region in agricultural production due to its high population density, markets and developed infrastructure as compared to other regions (World Bank, 2011). It is possible that in terms of total production, the western region performed best due to high population density, but these findings reveal that productivity at household level was the least. The results suggest that perhaps other factors beyond the control of the farmers, such as nutrient depletion and land degradation could be negatively impacting on the productivity and hence technical efficiency.

The central region of the country is covered in part by the Lake Victoria crescent, another area that was identified as hotspot of land degradation. Although originally regarded as high productivity area, nutrient depletion and hence soil infertility were reported to be a problem (NEMA 2010; Ronner and Giller 2012). Similarly the relatively low levels of technical efficiency observed during this period could be attributed to land degradation. However, MFPED 2010a observes that high levels of rainfall in the second season of 2009 and the first season of 2010 were responsible for high food crop output in the central region coupled with improved prices. This could explain the sharp rise in TE levels in the region in time periods 3 and 4 as improved prices and good rainfall provided incentive for production (Figure 1). Both the western and the central regions are regarded as high performance regions for agriculture (MFPED 2010b) however this study finds that the levels of productivity in the two regions was lower than in the rest of the country. Both areas were also noted by MFPED 2010b to have weak infrastructure constraining agricultural production, particularly poor road network deep in the areas where production takes place.

The factors that influence technical inefficiency of the farming households: The factors that are hypothesized to influence technical inefficiency of the farming households include the age, sex and education level of the household head, any information received on production during the farming season, the type of planting material used; whether local or improved, crop area and the time period in which production took place. The maximum likelihood estimates of the parameters of the

Table 9. Frequency Distribution of the TE scores.

TE Range	Central	Eastern	Northern	Western	Uganda
0.1 < TE ≤ 0.2	0	0	0	0	0
0.2 < TE ≤ 0.3	0	0	0	12 (20%)	12 (3.3%)
0.3 < TE ≤ 0.4	13 (12.3%)	0	0	25 (41.7%)	38 (10.4%)
0.4 < TE ≤ 0.5	60 (61.9%)	0	0	19 (31.6%)	79 (21.7%)
0.5 < TE ≤ 0.6	22 (22.7%)	2 (2%)	0	4 (6.7%)	28 (7.7%)
0.6 < TE ≤ 0.7	3 (3.1%)	17 (17.5%)	0	0	20 (5.5%)
0.7 < TE ≤ 0.8	0	51 (51.6%)	0	0	51 (14.01%)
0.8 < TE ≤ 0.9	0	28 (28.9%)	20 (18.5%)	0	48 (13.2%)
0.7 < TE ≤ 0.8	0	0	88 (81.5%)	0	88 (24.2%)
TOTAL	**98 (100%)**	**98 (100%)**	**108 (100%)**	**60 (100%)**	**364 (100%)**
Mean	0.464	0.75	0.936	0.367	0.667
Stan.Deviation	0.064	0.07	0.04	0.08	0.294
Range	0.322	0.378	0.19	0.326	0.77
Min.	0.323	0.518	0.802	0.224	0.224
Max.	0.646	0.896	0.994	0.55	0.994

inefficiency effects model are presented in Table 9.

Technical inefficiencies are not found to significantly influence variations in output in the northern and the eastern regions, as well as the country data, although certain variables are found to be significant in influencing the inefficiencies in the respective data. However the random component of the inefficiency effects is found to be significant for the northern region. The coefficient of gamma shows that they are responsible for 0.08% of total variation in output and the finding is significant at 10% level of significance. In the other two regions; the central and western, technical inefficiencies are found to be important in describing variations in output during the study period.

The coefficient of *age* carries a positive sign for the central, eastern, northern regions as well as the country data. This implies that as the age of the household head advances, technical inefficiencies increase. This is to be expected as older farmers are likely to be weak and less able to search for relevant information and services. The finding is significant at the 1% level only for the northern region where the mean age of the sample is 39.2 years. In the western region, the reverse is true. Younger farmers are found to be more efficient although the finding is not significant. Both findings are consistent with literature. Llewelyn and Williams (1996) in a study of technical efficiency of irrigated farms in Indonesia, find that efficiency increases, then eventually declines with age. Similarly Seyoum *et al.* (1998) find that younger maize farmers in Ethiopia are more efficient than older ones. Coelli and Battese (1996) find that older farmers in rice farms in Indonesia are more efficient in some provinces and less efficient in others. This mixture in the signs is not unexpected given the various effects that farmer age might have on efficiency (Coelli and Battese, 1996).

The coefficient of *sex* carries a negative sign for three of the regions; central, eastern, northern and the country data. Accordingly male household heads are associated with less inefficiency. Bagamba *et al*. (2004) observe that the efficiency of male household heads in the banana growing areas is associated with their access to production resources, which include land, extension services and credit for production. Asekenye (2012) in a study of technical efficiency among groundnut farmers in Uganda and Kenya, finds that even women's vast experience in groundnut production does not translate into higher productivity than their male counterparts. It is therefore possible that the underlying differentials in access to production resources could contribute to relatively higher efficiency of the male household heads. However, in the western region, male household heads are associated with more inefficiency although the finding is not significant. The marginal effect of *sex* is higher in the eastern region although significant for the northern region and the country data at the 5% level of significance. In these three samples, male household heads are found to be more efficient producers than their female counterparts. UBOS 2010 finds that the number of female headed households in the country increased from 27% in 2005/06 to 30% in 2009/10 considering both the rural and urban areas. Regionally, the increase was highest in the western followed by the eastern region from 24% to 31%, and 24% to 28% in 2005/06 to 2009/10 respectively. With this increase in the number of female headed households, continued effort to address the differentials in access to productive resources between men and women is likely to sustain productivity levels in agriculture.

The level of education was found to significantly reduce inefficiency effects in the central, northern and eastern regions. An extra level of education in the central and northern regions reduces inefficiency by 0.16% and 0.06% respectively. Both findings were significant at 1%. Both regions have the advantage of access to information and extension services; the central due to its specific location in the country, and the north due to the targeted interventions of government and other agencies during the study period. In the western region, however, an extra level of education was found to increase inefficiency in production. The finding was significant at 5%. It is widely accepted in Ugandan studies, that higher levels of education among household heads result into higher levels of efficiency in production (Bagamba et al., 2004; Hyuha et al., 2007; Asiimwe, 2008). The finding to the contrary, in the western region might imply that the more educated individuals find employment elsewhere outside agriculture. Table 1 further confirms this; the western region has 79.6% of the sampled household heads having attained only up to primary school education.

The coefficient on *year* indicates that as the time periods progressed, there was a reduction in inefficiency in the central, eastern and northern regions. The finding was significant at 10% in the central region and at 1% in the northern region. In the western region, inefficiency effects increased at a rate of 0.83% per year which was significant at 1% level of significance during the study period. Overall in the country data, inefficiencies increased although the finding was not significant. MAFAP, 2013 notes that the country's performance in agriculture during the period 2005-2011 was less impressive than expected, although the study finds that inefficiency effects reduced from low levels of efficiency at the beginning of the period (season 2 2005) to higher levels at the end of the period (season 1 2010) in three of the regions. Coelli and Battese (1996) point out that the coefficient of *year* in the inefficiency effects model which is also the time-trend variable picks up the influence factors which are not included in the model such as government programmes. It is therefore important to identify those other factors that could be responsible for driving efficiency changes during this period across the regions, which may not have been captured in the analysis. The rest of the variables; the information obtained on production, the type of seed planted and crop area, were not found to have a significant influence on the inefficiency of the households during the study period. On average only 8% of the households in the country sample reported having information on production from any source while only 7% reported using improved planting material.

Summary and Conclusion

The farming households in the country study sample were found on average to produce 70% of the maximum attainable output for given input levels during the study period. Although this shows that households in Uganda are fairly efficient in production, the study finds that there are regional differences in levels of efficiency, which justifies the analysis of technical efficiency at regional level. Furthermore, the wide range between the least (22.4%) and the most efficient (99.4%) households indicates that a lot of room still exists for improvement in technical efficiency.

Overall in the country data, male household heads are found to be more efficient than their female counterparts and the difference is found to be significant at 5%. Higher levels of education are found to significantly increase efficiency at the 10% level. Although the selected inefficiency variables do explain the inefficiency effects in the country sample, the inefficiency effects model is not an important component of the analysis of agricultural production at the country level. The foregoing discussion has important implications for investment in education by the government as a way of ensuring sustained productivity improvement. Higher levels of education were found to be important in improving technical efficiency in all the regions of the country. As such government efforts to support universal primary and secondary education in the country should offer promising results for agricultural productivity in the future. The significant difference between the efficiency levels of male and female headed households suggests that efforts to enhance women's access to productive resources could pay-off with improved productivity in the country's agriculture. The findings for the northern region suggest that targeted government intervention can be effective in addressing challenges that are specific to regions. Therefore in view of the fact that the central and western regions had factors significantly impacting on the levels of efficiency that were not captured in this study, it would be important for further research to identify the factors in order to step up targeted intervention for the two regions.

The factors noted elsewhere in literature include land degradation which might have been responsible for declining productivity particularly in the western region.

The other was the improved general price level for food crops in the regional and international markets which could have provided incentive for production and hence improvement in productivity especially towards the end of the study period. The study mostly captured food crops across the four regions suggesting that targeted intervention could focus on price incentives and access to markets for food crops that each region leads with relative advantage in production.

REFERENCES

Asekenye, C. (2012). "An Analysis of Productivity Gaps among Smallholder Groundnut Farmers in Uganda and Kenya" *Master's Thesis.* Paper 323, http://digitalcommons.uconn.edu/gs_theses/323

Asiimwe, J. (2008). "Technical Efficiency of upland rice producers in south western Uganda." Master's Thesis, Makerere University, Kampala, Uganda.

Bagamba, F., Ruben, R., Rufino, M. (2006). "Determinants of banana productivity and technical efficiency in Uganda." Chapter 8

Battese, G., Coelli, T. (1995). " A model for technical inefficiency effect in stochastic frontier production function for panel data," *Empirical Econo.* 20: 325–332.

Coelli, T., Battese, G. (1996). Identification of factors which influence technical inefficiency of Indian farmers. *Austr. J. Agric. Econ.,* 40(2): 103-128.

Coelli, T.J. (1996). A Guide to FRONTIER version 4.1: A computer program for Stochastic Frontier Production and Cost Function Estimation, Centre for Efficiency and Productivity Analysis (CEPA) Working Paper No. 7/96, University of New England (UNE), Armidale, Australia.

European Union (EU). (2007). Northern Uganda Agricultural Recovery Program (NUARP), An identification Study, Volume 2, Background Information, Final Report.

Government of Uganda (GoU) 2010. Agriculture for Food and Income Security: The Agriculture Sector Development Strategy and Investment Plan 2010/11-2014/15

Gujarati, D. (2004). *Basic Econometrics* (4th Edition), McGraw-Hill Companies.

Hyuha, T., Bashaasha, B., Nkonya, E., Kraybell, D. (2007). Analysing profit inefficiency in rice production in eastern and northern Uganda. *Afr. Crop Sci. J.* 15(4): 243-253.

Llewelyn, R., Williams, J. (1996). Nonparametric analysis of technical, pure technical, and scale efficiencies for food crop production in East Java, Indonesia. *Agric. Econ.*, 15: 113-126.

Ministry of Finance Planning and Economic Development (MFPED). (2010a). The Background to the Budget, 2010/11 Fiscal Year.

Ministry of Finance Planning and Economic Development (MFPED). (2008). "Agricultural Sector Investments and Institutional Performance in Uganda." Discussion Paper 17.

Monitoring African Food and Agricultural Policies (MAFAP). (2013). "Review of food and agricultural policies in Uganda, 2005-2010." MAFAP Country Report Series, FAO, Rome, Italy.

National Environment Management Authority (NEMA). (2010). "State of the Environment Report for Uganda, 2010."

NIMES. (2007) "The 2007 Annual PEAP Implementation Review- Main Report." October, 2007.

Obwona, M. (2002). "Determinants of technical efficiency differentials amongst small and medium scale farmers in Uganda: A case of tobacco growers." Economic Policy Research Centre (EPRC), Occasional Paper No.19.

Piesse, J., Thirtle, C. (1997). Sector Level Efficiency and Productivity in Hungarian Primary, Secondary and Tertiary Industries, 1985-91, *Eastern Eur. Econ.*, **35**: 5-39.

Plan for Modernisation of Agriculture (PMA). (2007). "PMA Contributing to Transformation." In the PMA Quarterly Bulletin-From Poverty to Prosperity. Vol.5 No.1. September, 2007.

Ronner, E., Giller, K. (2012). Background information on agronomy, farming systems, and on-going projects on grain legumes in Uganda. www.N2Africa.org

Seyoum, E.T., Battese, G.E., Fleming, E.M. (1998). Technical efficiency and productivity of maize producers in eastern Ethiopia: A study of farmers within and outside the Sasakawa-Global 2000 project. *Agric. Econ.*, 19: 341-348.

UBOS (2009). Uganda National Panel Survey 2009/10: Interviewer's Manual of Instructions.

UBOS (2010b). Uganda National Report for the Implementation of the Program of Action for the Least Developed Countries for the decade 2001-2010.

UBOS (2010) Uganda National Household Survey 2009/10: Socio-Economic Module, Abridged Report.

UBOS (2011). Statistical Abstract, 2011.

Uganda Bureau of Statistics (UBOS). (2007). Uganda National Household Survey 2005/06. Report on the Agriculture Module.

World Bank.(2011). Uganda: Agriculture for Inclusive Growth. Draft Fin al Report, June, 2011.