OF WHAT MERIT IS IMPROVED INPUTS USE IN UGANDA'S MAIZE PRODUCTIVITY?

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ABSTRACT

This paper used the Uganda National Household Survey (UNHS) dataset of 2005/06 to examine the productivity of improved inputs used by smallholder maize farmers in Uganda. Yield and gross profit functions were estimated with the stochastic frontier model. Results revealed a significant effect improved inputs use on yield but not gross profit. Farmers who used commercial improved seed with fertiliser obtained superior yield but lower gross profit compared to farmers who planted recycled seed (of improved variety) without fertiliser. Furthermore, if the opportunity cost of own land and labour inputs in maize production were imputed, overall, farmers made economic losses. Based on the prevailing farmers' production technology and market conditions, maize cultivation in the range of 2-3 ha was found to give optimum profit while cultivation under 1 ha or above 4 ha led to economic losses. The key finding of this paper is that use of improved inputs by Ugandan farmers in maize cultivation yields sub-optimal profits due to higher marginal cost compared to marginal revenue from increased output associated with improved inputs use. And, overall, maize farming is of no economic benefit -other than for food.

Key words: Improved inputs, productivity, Uganda
JEL Classification: Q12, Q16

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1.0 INTRODUCTION

By any measure, Uganda is an agricultural country. Despite the declining contribution of agriculture to overall Gross Domestic Product (GDP) –now estimated at 15.1 percent, the sector remains the main source of livelihood to nearly 73 percent of the Uganda's labour force (Uganda Bureau of Statistics -UBoS, 2006). The bulk of Uganda's exports are agricultural commodities and much of the industrial activity is in agro-processing. Growth of agriculture is critical to the growth of the overall economy and poverty reduction in Uganda (Sennoga and Matovu, 2010). However, despite the fact that rapid growth in agriculture is important for Uganda, it remains dismal –averaging 1.3 per cent over the past 5 years (MFPED, 2009).

Countries –particularly in Asia that have registered consistently high grow rates in agriculture have also been associated with sizeable increases in the use of improved production technologies compared to other inputs including land or labour (Hazell and Rosegrant, 2000). Increases in per capita use of fertiliser, high yielding seed varieties, traction power and irrigation are particularly commended for the Asian green revolution (World Bank, 2007).

In the case of Uganda, however, use of improved agricultural technologies remains low (UBoS, 2007) -even when most farmers may be aware of the potential of these inputs to increase yield. But yield per se may not be enough to guarantee increased adoption -especially for poor farmers when the cost of these inputs compared to the farmers' basic needs may be relatively high. The economic returns from use of these inputs of essence than yield (FAO, 2006).

This paper therefore sought to examine the contribution of improved inputs use to farmer yield and profit in Uganda's maize sub-sector. To this end, the overall objective of this paper was to examine the economic as compared with the physical productivity of improved inputs use in smallholder maize production. The specific objectives were:

- (i) To compare the yield and profit of smallholder farmers under various input-mix production practices;
- (ii) To examine the contribution of improved input to productivity, and
- (iii) To examine the relationship between farmer attributes and productivity.

By concurrently analysing the impact of improved inputs use on the physical and economic productivity, this will shade light on the less-often asked but important question of why farmers are not using improved technologies in Uganda -than would be expected. Certainly, a better understanding of the farmer's physical as compared to economic productivity from their diverse input-mix production practices is key to appropriate policy intervention. Also, given the fact that the revised 5-year (2010/11- 2014/15) Development Strategy and Investment Plan (DSIP) of Ministry of Agriculture Animal Industry and Fisheries (MAAIF) (MAAIF, 2010) is focussing on investing in the maize sub-sector as one of the 10 strategic crops, results of this paper should be of interest to policy-makers.

The remainder of the paper is organised into 4 sections. A brief overview of Uganda's maize sub-sector is presented in the next section, which is followed by the review of literature. Section 4 describes the data and the method of analysis. Empirical results and discussion is given in Section 5 while the conclusion and implications of the study are given in the last section.

2.0 OVERVIEW OF UGANDA'S MAIZE SUB-SECTOR

Maize is a very important crop in Uganda. It is the most highly cultivated crop. Statistics from the Uganda National Household Survey (UNHS) of 2005/06 show that maize was cultivated on an estimated area of 1.54 million hectares (ha) by about 86 percent of the 4.2 million agricultural households (Uganda Bureau of Statistics (UBoS), 2007). Maize is the number-one staple for the urban poor, in institutions such as schools, hospitals and the military. Also, the crop is the number-one source of income for most farmers in eastern, northern and north-western Uganda (Ferris et al, 2006).

Other than food, maize has had a wide range of other uses -including processing of livestock and poultry feeds and making of local brew. All this has made maize is the most traded food-crop in Uganda. Maize grain was the first food crop to be traded under the Uganda warehouse receipt system (WRS) -since the inception of WRS services in 2006 (Rural Savings Promotion and

Enhancement of Enterprise Development –SPEED, 2006)[1]. Besides, in the same year of 2006, maize topped the list of food exports, earning the country over $24 millions[2].

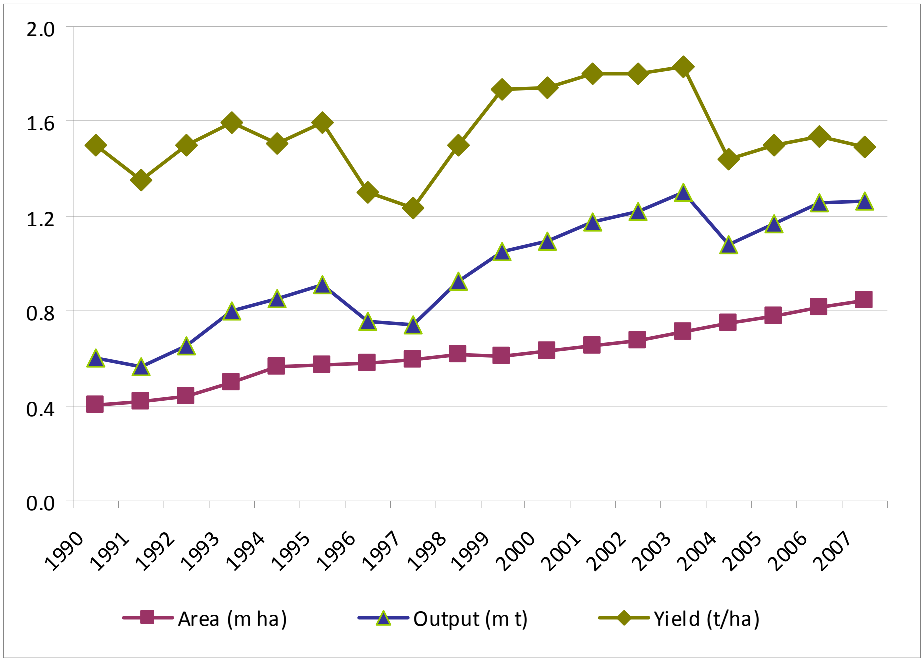
Although there are many other industrial formulations that can be developed from maize, this component of the value-chain is not yet fully exploited in Uganda's maize sub-sector. For example, maize is used in the manufacture of cooking oil, ethanol-which is an additive in gasoline (bio-fuel), starch and syrup –which are used in the manufacture of medicines.

Because of the multiplicity of uses, maize is highly regarded as a strategic food security crop in Uganda. This is even outlined in the revised DISP (MAAIF, 2010). Maize is the only cereal crop selected as part the 10 priority crops government is to support under the revised DSIP. The planned government intervention in the maize sub-sector is in the area of seed multiplication and distribution, extension services provision, establishment of warehouses, and research.

However, like other food-crops, maize cultivation in Uganda is on smallholder farms – characterised by low and sometimes declining productivity. According to 2005/06 UNHS report, between 1999/2000 2005/06, the number of plots under maize have increased over five-fold from 1539 to 8422 million, but average plot size has declined. Decline in area cultivated has been blamed on the increasing agricultural households yet farmland remains relatively fixed. Production statistics from the Food and Agricultural Organisation of United Nations (FAO)[3] show that while Uganda's maize output has more than doubled -from 0.6 to 1.26 million tonnes over the last 2 decades (1990-2007), yield has declined from about 1.8 tonnes per hectare (t ha^{-1}) in 2004 and has now levelled-off to 1990 yield of 1.5 t ha^{-1} (Figure 1). Comparing farmer average yield (1.5 t ha^{-1}) with researcher-managed yield (7 t ha^{-1})[4] however, it is clear that there still remains a huge gap between actual and potential maize yield in Uganda.

[1] Though other crops traded under the Uganda WRS are paddy rice, coffee and cotton, maize remains the dominant and most successful traded commodity.
[2] http://www.ugandaexportsonline.com/docs08/statistics/export_stats_2002-06.pdf
[3] FAOSTAT. http://faostat.fao.org/site/339/default.aspx , accessed August, 2009.
[4] Technologies released at NAARI- http://www.naro.go.ug/technologies/naaritechn.htm

Figure 1: Area cultivated, output and yield of Maize in Uganda



Source: Author's own calculations based on FAO data

Limited use of improved inputs including improved seed, fertilisers, herbicides/ fungicides and traction power in production -by farmers, is widely regarded as the major constraint to agricultural productivity growth in Uganda (Ministry of Finance Planning and Economic Development (MFPED), 2008; MAAIF, 2010). Statistics from UBoS (2007) show that just 6, 1 and 3 percent of farming parcels planted with crops in Uganda used improved seed, fertilisers, and herbicides/ fungicides respectively in production. Beside low use, the quality of inputs on the market is in many instances is tampered with[5], which also greatly affect productivity. Other than low use and tampered quality, however, inefficient use of improved inputs such as fertilisers by farmers in Uganda is not uncommon.

[5] See www.monitor.co.ug, "Naads seeds fail to germinate", Jul 14, 2008 by James Eriku

3.0 REVIEW OF RELATED LITERATURE

Inquiry into the contribution of agricultural inputs (including the quality of inputs) to output variation or factor productivity and total factor productivity in cross section or over time continues to attract research interest, though it is not new. Heady (1946) as quoted in Mundlak (2001) pioneered work in agricultural productivity analysis by estimating the Cobb and Douglas function on farm-level data. In the analysis, Heady (1946) calculated the elasticities of land, labour and other assets and variable inputs (read improved inputs) in production. Besides quantity, the quality of the inputs as well as farm management were regarded as important factors in production variation –but were never included due to lack of appropriate data, Mundlak (2001).

Since then, there has been an upsurge of studies on agricultural productivity, be it at farm or aggregate level; national or cross-country; and cross-sectional or longitudinal. Most of these studies however have focussed on physical productivity (yield) in isolation of the economic productivity. Yet the economic productivity of the input –as indicated by the value to cost ratio, is one of the most important determinants of its adoption (FAO, 2006). Moreover, studies that have concurrently analysed the contribution of factor inputs to physical and economic productivity (for example, Bravo-Ureta and Pinheiro, 1997) show that in most of the cases, there is a marked difference.

The method of analysis of agricultural productivity has to a great extent evolved from the predominantly Cobb-Douglas production function estimation approach to other methods such as the translog function (for example, Ray, 1982; Hyuha et al., 2007), the quadratic function (Shumway et al., 1988; Huffman and Evenson, 1989), the data envelop analysis (Chavas and Cox, 1988; Tauer, 1995; Coelli and Rao, 2003), and the stochastic frontier analysis (SFA) (for example, Ali and Flinn, 1989; Kolawole, 2006; Oladeebo and Fajuyigbe, 2007). Of all the methods, the SFA has however gained more prominence in recent years.

Concerning the impact of improved inputs on productivity, most studies are unanimous of the positive and significant impact of fertiliser on yield (World Bank, 2007). But results of the economic returns of fertiliser remain mixed. For example, Kelly and Murekezi (2000) found that fertiliser use in most areas of Rwanda was profitable for some crops (such as maize and potatoes) but not for others –for example, sorghum and beans. In the case of seed, the World Bank (2007) provides extensive literature of the positive impact of improved seeds varieties on yield in Asia and even in Sub-Saharan Africa, but little is said on the economic returns from using these seeds especially for smallholder farmers in Africa.

The influence of farmer characteristics and farm attributes on productivity has received great attention in productivity analysis. For example, studies including Owens et al. (2003), Evenson and Mwabu (1998), Bravo-Ureta and Evenson (1994), Kalirajan (1991) report a positive and significant relationship between farm-level yield and access to extension services. In the case of education level, results are mixed. Some studies report a positive and significant relationship between education level and yield (Evenson and Mwabu, 1998), others report an inverse relation (Aguilar, 1988 as cited by Evenson and Mwabu, 1998) and yet other studies have reported no statistical significance (Bravo-Ureta and Evenson, 1994).

The issue of gender in productivity has received a fair share of research attention. A study of gender efficiency in agricultural production by Udry (1994) in Burkina Faso found that that plots controlled by women had notably lower yields than similar plots controlled by men within the same household planted with the same crop in the same year. Udry however noted that yield differentials were due to allocative, rather than technical inefficiency of women managed farms given the significantly higher labour and fertiliser inputs per acre on plots controlled by men. Saito et al (1994) also reported a positive although insignificant coefficient of gender (male plot manager) effect on yield -in a study in Kenya.

The effect of weather on farmer yield has been analysed by Akpalu et al. (2008). Using precipitation and temperature data, the authors found that a unit increase in the mean precipitation had a considerably favourable impact on yield while a decrease in precipitation had a negative impact on the yield of maize farmers in South Africa.

Rahman (2003) used a stochastic profit frontier function to model the profit inefficiency effects that may arise from farmer characteristics and access to extension and infrastructure services among other factors. Results of his study indicated that soil fertility, access to extension and farmer experience were positively associated with increased profit efficiency. Using farm-level survey data and SFA approach, Kolawole (2006) also reported that age, farmer experience, education level, and household size positively affected the profit efficiency of small scale rice farmers in Nigeria.

Analysis of agricultural productivity in Uganda has attracted a reasonable number of studies, most especially in the area of land productivity. Using the Uganda Integrated Household survey data of 1992/3 and 1993/94, Deininger and Okidi (2001) show that increase in value of farmers' output was positively associated with the value of land, labour and fertiliser used in production. Years of experience and the level of education were also found to play a positive role in increasing household output. In an earlier study, Appelton and Balihuta (1996) had also found a positive relationship between education level and household agricultural output. Okello and Laker-Ojok (2005) found that farmer productivity was significantly influenced by land topography, level of rainfall, incidence of pests and diseases, and infrastructural developments. Other factors found to significantly affect farmer productivity included the level or value of investment in agricultural production inputs. Hyuha et al. (2007) is one the few studies that analysed farmer productivity from the profit viewpoint. The study was however limited to just 3 rice growing districts of Tororo, Pallisa and Lira in eastern and northern Uganda. In all these studies cited, however, none appears to have simultaneously considered the impact of improved inputs use on physical and economic productivity.

Studies that have comparatively analysed the impact of improved inputs use on both yield and profit are scanty in general and virtually absent in the case of Uganda. In the analysis of either physical or economic productivity, the SFA method has gained prominence due to its ability to concurrently estimate the significance of both the stochastic noise and the inefficiency of farm/farmer attributes in productivity. This paper adopts the SFA modelling approach to examine the relationship between the level of farmer expenditure on improved inputs and yield and profit in maize farming in Uganda.

4.0 DATA AND METHODS

4.1 Data

This paper utilized the Uganda National Household Survey (UNHS) data set of 2005/06 collected by the Uganda Bureau of Statistics (UBoS). This dataset is national in scope. It was collected at household and community level for two seasons and on five modules, namely: agriculture, socioeconomic, community, price, and qualitative modules. Agriculture, which was the core module, covered household crop and non-crop farming enterprises. On crop enterprises, enquiries were made -for example on area under crop(s), quantity and value of labour inputs, output and sales, value and attributes of non-labour inputs. The non-crop section covered livestock and poultry production and deposition. The socio-economic module included farmer characteristics such as location, age, gender, education level, access to extension services, and access to credit. The Price module mainly covered market prices for agricultural inputs and outputs.

For this paper, data pertaining to maize production and relevant to the objectives were filtered from the 5 modules and then merged using unique identifiers. A total of 1888 farm (parcel) observations, distributed by region as in Table 1 were derived. The units of measurement and the descriptive statistics of mean, standard deviation, minimum and maximum value of the variables are also given in Table 1. The descriptive statistics reveal that the average area cultivated with maize was 0.31 ha with the highest area cultivated being 32.4 ha. Farmer expenditure on improved inputs that comprise improved seed, fertiliser, herbicides/fungicides, traction power and manure averaged UGX 7170, 680, 1050, 7220, and 480 ha^{-1} respectively but with a wide variance as indicated by their standard deviation.

Table 1: Variables of the study, their units of measurement and descriptive statistics.

Variables	Unit of measure/number (n) of observations	Mean/ proportion	Std. Dev.	Minimum	Maximum
Region	1=central; 2=eastern; 3=northern; 4=western	0.20; 0.45; 0.19; 0.17			
Area cultivated	Hectares (ha)	0.311	0.835	0.001	32.37
Seed cost	UGX ha^{-1}	7169	24586	0	370650
Fertiliser cost	UGX ha^{-1}	684	9111	0	222390
Herbicide/fungicide use cost	UGX ha^{-1}	1054	9448	0	217448
Traction/power cost	UGX ha^{-1}	7220	29773	0	370650
Manure cost	UGX ha^{-1}	483	12152	0	494200
Hired labour value	UGX ha^{-1}	24943	97998	0	1853250
Family labour use	man-days ha^{-1}	92.0	104.7	0.0	2149.8
Hired labour	man-days ha^{-1}	11.9	44.4	0.0	840.1
Agriculture labour wage	UGX man-day^{-1}	1276	773	300	8000
Output price	UGX kg^{-1}	198	106	1	1063
Input /farmer attributes					
Fertiliser use	1=yes, 0=no	0.01	0.12	0	1
Herbicide/fungicide use	1=yes, 0=no	0.03	0.18	0	1
Traction/power use	1=yes, 0=no	0.11	0.32	0	1
Manure use;	1=yes, 0=no	0.03	0.16	0	1
Gender	1=male, 0=female	0.78	0.41	0	1
Household size	Number	6.5	3.4	1	33
Farmer age	years	42.9	14.8	18	97
Cropping pattern	1=pure stand, 0=intercrop	0.38	0.49	0	1
NAADS in area;	1=yes, 0=no	0.23	0.42	0	1
Extension visit/training	1=yes, 0=no	0.08	0.27	0	1
Seed type	1=Home-saved local (HSL) seed; 2=Market-sourced local (MSL) seed; 3=Home-saved improved (HSI) seed; 4=Market-sourced improved (MSI) seed	0.62; 0.20; 0.07; 0.11		1	4
Education level categories	1=less than primary 1; 2=primary; 3=Ordinary level; 4=Advanced level secondary; 5=degree/specialised training	0.17; 0.58; 0.17; 0.01; 0.08		1	5

Source: Author's calculations based on UNHS 2005/06 data

While on average farmers spent most on hired labour (UGX 24943) than all other inputs combined (about UGX 17000), family labour use (92 man-days) outstripped hired labour use (11 man-days) by 8 times. This suggests that labour in general and family labour in particular was the dominant input in production. The proportion of farmers using improved inputs in production is shown in Table 1, being 1, 3, 11, and 3 percent for fertiliser, herbicides/fungicides, traction power and manure respectively. The majority of the farmers planted local maize seed (82 percent) -either saved from past production (62 percent) or sourced from the market (20 percent) while only 11 percent planted improved seed sourced from market.

The demographic characteristics of the farmers, indicate that 78 percent of the farm managers were male, the average age of the farmers was 43 years and the average household size was 7 persons. The majority of the farmers (58 percent) had primary education, 17 percent had no formal education while another 17 percent had ordinary level education. The majority of the farmers inter-cropped (62 percent) maize with other crops. Only 8 percent of the farmers received extension training and/or services.

4.2 Method of analysis

To examine the contribution of improved inputs use in farmer productivity, we follow the approach of Kumbhakar and Lovell (2000) and estimate a stochastic frontier production model of the Cobb-Douglas function for yield and gross profit, specified as:

$$y_i = f(A_{ki}, x_{ji}, \beta).e^{\varepsilon_i}\ ;\ i = 1, \ldots\ldots N, \qquad 1$$

Where y_i is yield or gross profit of farmer i; A_{ki} is the area k under cultivation by farmer i, x_{ji} is the cost of input j used in production by farmer i, β is a vector of coefficients to be estimated. e is the expression for exponential, and ε_i is the error term, consisting of the stochastic term, ν_i and the inefficiency variables –farmer characteristics, u_i. That is; $\varepsilon_i = v_i - u_i$. The ν_i*'s* are assumed to be normally distributed and independent of u_i*'s*. While u_i*'s* are non-negative random variables associated with the (in)efficiency in the yield/gross profit. Since the data we used was cross-sectional, a half-normal distribution of the inefficiency variables was assumed in order to obtain efficient estimates (Bauer, 1990).

In general, the model in Eq [1] was composed of two parts –the general model-*f*(.) and the inefficiency model (ε). In the explicit form, Eq [1] was specified as in Eq [2].

$$y_i = \alpha_0 + \alpha_1 \ln A_{ji} \sum_{j=2}^{6} \alpha_j \ln X_{ji} + \left[v_{ji} + \left(\beta_0 + \sum_{k=1}^{9} \beta_k z_{ki} \right) \right] \qquad 2$$

In Eq [2], *ln* implies natural logarithm, $X_{1i}, X_{2i}, .., X_{6i}$ are costs of seed, chemical fertiliser, herbicides/fungicides, hired labour, manure, and traction power, respectively for farmer *i*. On the other hand, $Z_1, Z_2, .., Z_9$ were farmer characteristics including family size, gender, age, education level and urban/rural location. Other farmer characteristics included were cropping pattern, season of farming, extension services access, and farmer being in area where NAADS operated.

Positive values of the inefficiency covariates (Z's) indicate the contribution of the variable towards the overall productivity inefficiency. However, if the value of the inefficiency covariate is negative, the variable brings about efficiency rather than inefficiency towards the overall yield/ gross profit of the farmer.

The variables included in Eq [2] are those that are normally included in analyses of this kind, including studies such as Ali and Finn (1989), Bravo-Ureta and Pinheiro (1997), Rahman (2003), and Hyuha et al (2007). Estimation of the parameters (α, β, ν) in Eq [2] was carried out in one-step using the maximum likelihood estimation technique in the Frontier models programme of STATA/SE 10.0 SE.

5.0 RESULTS

5.1 Yield and labour productivity

Table 2 shows that the national average yield of maize was 1.94 t ha^{-1} -coming from an average cultivated area of 0.31 ha. Farmers in western cultivated the highest average area of about 0.39 ha of maize while farmers in central and northern cultivated the lowest of 0.26 ha. In terms of yield, however, farmers in western obtained the second lowest average of 1.86 t ha^{-1} while farmers in eastern obtained the highest average yield of 2.2 t ha^{-1}. Farmers in northern Uganda obtained the lowest output and yield.

Table 2: Yield and labour productivity

Region	Area (ha)	Output (t)	Yield (t/ha)	Total labour (man-days)	Labour productivity (kg/man-day)
Central	0.26	0.50	1.95	96.10	5.23
Eastern	0.32	0.72	2.21	101.72	7.04
Northern	0.26	0.37	1.42	80.55	4.61
Western	0.39	0.73	1.86	145.81	5.00
Total	0.31	0.61	1.94	103.91	5.83

Source: Author's own calculations based on UHNS 2005/06 data

Table 2, also shows that the physical labour productivity in maize production at the national level was 5.8 kg $man\text{-}day^{-1}$, arising from 103.9 man-days of total labour (which includes both hired and family labour input). By region, results indicate that the physical labour productivity in maize production was highest in eastern (7.04 kg $man\text{-}day^{-1}$), followed by central. Again northern had the lowest physical labour productivity.

Table 3 compares the maize labour productivity value with the agricultural labour wage. Physical labour productivity is converted into labour productivity value at the average price of output. The last column of the Table 3, which gives the ratio of labour productivity value to agricultural labour wage, indicates that only eastern Uganda had the value of labour productivity higher than agricultural wages. The implication of this ratio is that at the prevailing of state of production technique and market conditions, it was probably better to hire-out labour than engage it in maize production -since on average the return to labour employed in maize production was lower than the market wage rate.

Table 3: Comparison of labour productivity and labour wage

Region	Physical Labour productivity (kg/man-day)	Output price (UGX/Kg)	Value Labour productivity (UGX/man-day)	Agriculture labour wage (UGX/ man-day)	Ratio of labour productivity/ Agriculture wage
Central	5.23	213.2	1115	1775	0.6
Eastern	7.04	190.1	1339	1178	1.1
Northern	4.61	202.3	933	1046	0.9
Western	5.00	194.9	974	1214	0.8
Total	5.83	197.7	1152	1276	0.9

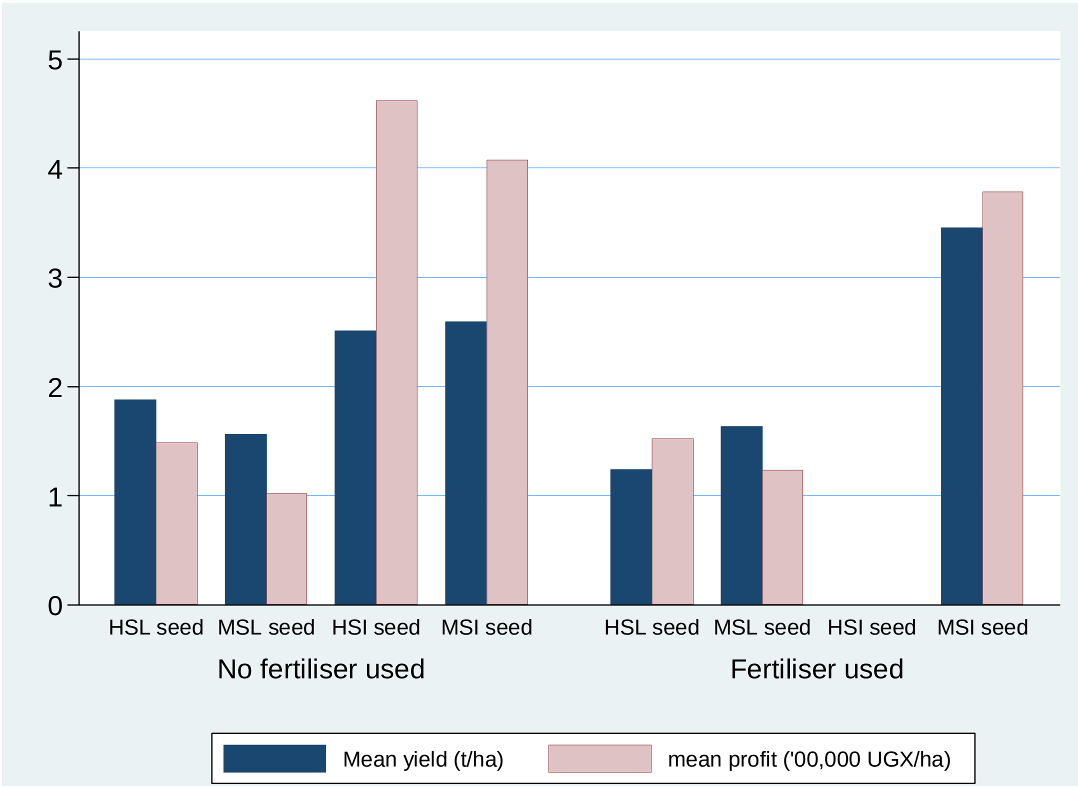
Source: Author's own calculations based on UHNS 2005/06 data

5.2 Comparison of yield and gross profit against seed type and fertiliser use

Assuming the effect of other production inputs such as labour on land productivity to be constant, Figure 1 compares the farmers' yield and gross profit on the basis of seed type and fertiliser use in production. The graph depicts a number of interesting scenarios of the physical as well as economic returns from improved inputs use, which would not be apparent if the two graphs were drawn independent of another.

Considering yield, first, it is clear from the graph that farmers who applied fertiliser on market-sourced improved (MSI) seed (considered best quality seed) obtained a highest average yield (about 3.5 t ha^{-1}) compared to any other fertiliser-seed input mix. This suggests clearly that good quality maize seed especially procured from certified traders is responsive to fertiliser -when applied effectively. Second, farmers who planted improved seed (either HSI or MSI) -even without fertiliser, obtained higher yield than farmers who used local seed. For example, farmers who planted either HSI or MSI but without fertiliser obtained an average yield of 2.5 t ha^{-1} compared to farmers who planted local seed (either MSL or HSL) and obtained average yield of less than 2 t ha^{-1}.

Figure 1: Yield and gross profit comparison by seed type with and without fertiliser use



Source: Author's own calculations based on UHNS 2005/06 data

The third and last observation we make from Figure 1 regarding yield is that farmers who applied fertiliser on local seed, obtained either the same yield (in the case of MSL seed) or lower yield (HSL seed) – suggesting that local seeds may be less or non-responsive to fertiliser.

Turning to gross profit in relation yield outcomes, the following is noted. Firstly, in general, farmers who planted improved seeds (HSI and MSI) either with or without fertiliser, obtained higher gross profit than those who planted local seeds (HSL and MSL). Secondly, although farmers who planted MSI seeds with fertiliser obtained the highest yield, those who planted MSI seeds without fertiliser obtained slightly higher profit compared to farmers who planted MSI seeds with fertiliser. This suggests that the value of the marginal yield from fertiliser use on MSI seed was lower than the marginal cost of fertiliser. Thirdly, farmers who planted HSI seeds without fertiliser obtained the highest profit even though their yield was lower by about one tonne as compared with farmers who planted MSI with fertiliser. Ceteris-paribus, this result further suggests that the marginal cost of fertiliser is likely to be higher than the marginal revenue from increased fertiliser use in maize cultivation in Uganda. This may be one of the reasons for the low level of fertiliser use in Uganda. That it does not make economic sense to use fertiliser given other options. The fourth and last observation we make from the gross profit graphs is that application of fertiliser on local maize seeds is of no consequence either on physical or economic productivity.

5.3 Costs and returns in maize production

Table 4 shows the farmers' average expenditure on improved inputs, hired labour as well as the opportunity cost of farmers' own inputs (family labour and land). The total variable cost (TVC) is the sum of all monetary costs while the net profit is the gross profit less imputed costs. Overall, results reveal that farmers in Uganda (with the exception of Eastern) spent more on hiring labour than improved inputs. In particular, farmers in western spent on average three times more on hiring labour (UGX 0.051 million) compared to their expenditure on improved inputs (UGX 0.017 million), while in central farmers spent twice more on labour than improved inputs.

Table 4: Average expenditure and returns per hectare of maize, UGX millions

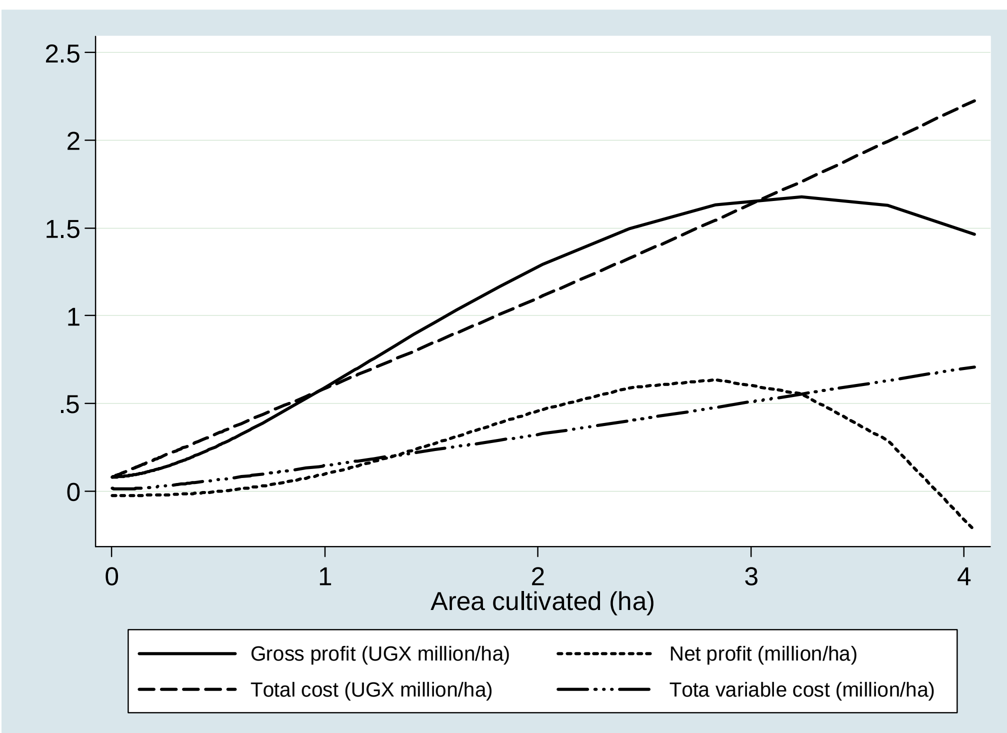
Expenditure item	Central	East	North	West	National
Improved (capital) inputs	0.014	0.019	0.013	0.017	0.017
Hired labour	0.031	0.017	0.015	0.051	0.025
Total variable cost	0.045	0.036	0.028	0.068	0.042
Total revenue	0.204	0.247	0.134	0.299	0.226
Gross profit	0.158	0.211	0.107	0.230	0.184
Imputed cost of family labour and own land	0.277	0.233	0.133	0.380	0.247
Net profit	-0.119	-0.022	-0.026	-0.149	-0.063

Source: Author's own calculations based on UHNS 2005/06 data

Although farmers in western Uganda got the highest gross profit, on the economic scale, they made the highest loss (UGX 0.15 million). Also, farmers in Central also obtained second highest economic loss of UGX 0.12 million on account of the high opportunity costs of labour and land. As a proportion of the total revenue, the farmers' TVC in maize production was merely 20 percent and the gross profit 80 percent. However, when the opportunity cost of family labour and land are imputed into the production costs, the net profit from maize became negative at national as well as for all regions. This clearly suggests that in 2005/06, maize cultivation in Uganda was of no economic consequence.

Following from the costs and returns in Table 4, Figure 3 presents the estimates of the costs and profit as area under maize increases. The graph shows that taking total variable costs per se, farmers' gross profit significantly increased with increase in area cultivated up to about 3 hectares and thereafter declined. That is, farmers cultivating an average of 1 ha made an average gross profit of 0.5 million while those cultivating an average of 3 ha made an average gross profit of at least 1.5 million. With inclusion of the opportunity cost of labour and land, however, the graph indicates that farmers' net profit grew modestly reaching about 0.5 million at 3 ha and thereafter declining rapidly. Farmers cultivating less than 1 ha or more than 4 ha on average made economic losses. Furthermore, the graph suggests that the area cultivated that yield optimal gross as well as net profit was in the range of 2-3 ha.

Figure 3: Estimated costs and returns based on area cultivated



Source: Author calculations based UNHS 2005/06 data

5.5 Econometric results and discussion

Results of maximum likelihood estimation of Eq [2] for yield and gross profit functions are presented in Table 5. Wald chi-square statistics for both the yield and gross profit functions were statistically significant at less than 1 percent, suggesting that the models were robust. In particular, the bootstrap least squares estimation technique was applied on the yield model while the weighted least squares method was applied in the gross profit model to improve the efficiency of the estimates.

Table 5: Maximum likelihood estimates of the yield and gross profit –half normal model

	Dependent variables				
	ln(yield) –(t ha^{-1})		gross profit (UGX millions ha^{-1})		
Explanatory Variables	Coef.	Bootstrap Std. Err.	elasticity	Coef.	Robust Std. Err.
ln(area cultivated)	-0.410***	0.03	0.83	0.156**	0.02
ln(seed cost)	0.001	0.01	0.02	0.003	0.00
ln(chemical fertiliser cost)	0.046**	0.02	0.04	0.007	0.01
ln(herbicides/fungicides cost)	0.018	0.02	0.02	0.003	0.01
ln(traction power cost)	0.023***	0.01	0.03	0.005	0.01
ln(hired labour cost)	0.026***	0.01	0.02	0.003	0.003
ln(manure cost)	-0.035	0.04	-0.09	-0.017**	0.01
Intercept	7.323***	0.11		0.457***	0.04
lnsig2v					
Intercept	-0.634***	0.12		-1.599***	0.20
Inefficiency model [lnsig2u)]					
Urban/rural	0.150	0.13		1.319	1.78
household size	-0.065***	0.01		-0.213**	0.09
gender	-0.230**	0.10		1.002	0.90
age	0.001	0.003		-0.055***	0.02
education level	-0.030	0.04		-2.185***	0.48
Cropping pattern	-0.088	0.09		0.794	0.58
farming season	1.202***	0.14		0.284	0.57
extension services access	-0.341**	0.15		-36.144***	4.83
NAADS	0.159*	0.09		-0.992	0.89
Intercept	0.644***	0.25			
sigma v	0.73	0.04		0.450	0.04
Number of observations	1888			1888	
Replications	500				
Wald $chi^2(7)$	205.74			70.21	
Prob > chi2	0.00			0.00	
Log likelihood/pseudolikelihood	-2930.5			-816230.39	

Source: Author's own calculations based on UHNS 2005/06 data

The second column in Table 5 shows the results the determinants of farmers' yield. For the five variables considered under improved inputs, results indicate that only farmer expenditure on fertiliser and traction power had a positive and significant effect on yield. This result, which is consistent with other studies including Deininger and Okidi (2001) and Bravo-Ureta and Pinheiro (1997), suggests that a unit increase in farmer expenditure on fertiliser and traction would improve yield by 4.6 and 2.3 percent respectively. Though positive, farmer expenditure on seed and herbicide/fungicide had no significant effect on yield.

Increased yield was also associated with increased farmer expenditure on hired labour. Other studies with similar findings, include Appletopn and Balihuta (1996), Deininger and Okidi (2001) and Bravo-Ureta and Pinheiro (1997). Just as is the case with the use of traction power, increased productivity due to use of hired labour may be due to effective weed management arising from quicker weeding completion rates by hired labour. Table 6 also shows that increase in area cultivated by 1 hectare significantly reduced yield by up to 40 percent –which is the typical stylised inverse relationship between area size and yield observed in almost every study on land productivity.

According to the results of the yield inefficiency model, presented in Table 6, the coefficient of household size was negative and statistically significant at less than 1 percent. This result is consistent with Deininger and Okidi (2001) and Iheke (2008) and implies that farmers with larger families were less inefficient or had higher yield than those with smaller families. Relatively larger families enhance labour availability, which most likely reduces the time rate taken to complete land preparation and as well increases the frequency of cultivation to control weeds -which are a recognised constraint to yield (Tittonell, 2007).

The gender coefficient was found to be negative and statistically significant with respect to yield. A negative gender coefficient, consistent with Udry (1994) and Saito et al (1994) suggests that male farmers were associated with lower inefficiency or higher productivity than their female counterparts. This is most likely due to the higher allocation of funds on improved inputs by male than female farmers –due to their better economic prospects.

National poverty level estimates show that male persons in Uganda are relatively less poor than their female counterparts (MFPED, 2004). And, a simple variance analysis (not included in the results of this paper) revealed that male farmers spent relatively higher amounts (UGX 0.016 million ha^{-1}) on improved inputs in maize cultivation compared to female counterparts (UGX 0.010 million ha^{-1}).

The result concerning farmer access to extension services was negative and significant - suggesting that farmer access to extension services enhanced yield. The result is similar to the findings of Evenson and Mwabu (1998) and Owens et al. (2003). Using the UNHS dataset of 1992/93, Deininger and Okidi (2001) also found a positive but not statistically significant relationship between farmer access to extension services and productivity. The authors attributed the lack of significance in their results to the general decrease in agricultural productivity in Uganda in the year 1992/93.

The highly positive and significant coefficient associated with the season variable –a proxy for weather, suggested that farmers' yield was sensitive to precipitation and sunshine (weather) conditions. This result, which is consistent with Okello and Laker-Ojok (2005) and Akpalu et al. (2008), indicated that farmers who cultivated maize in the first season of 2005 had markedly lower yield compared to farmers who cultivated in second season of 2004. In Uganda, smallholder agriculture is entirely dependent on rainfall. Thus, variation in farmers' yield was mostly likely related to the differences in the level and pattern of rainfall.

The last variable to consider in explaining yield is NAADS, which was found to have a positive but weakly significant (9 percent) correlation with yield. This result suggests that farmers who were involved in NAADS enterprises and as well cultivating maize may have had relatively lower yield compared to farmers not engaged in NAADS activities. This result appears to be in line with the finding by Benin et al. (2007) -that despite positive effects of NAADS on adoption of improved production technologies and practices, no significant differences were found in yield growth between NAADS and non-NAADS sub-counties for most crops. Benin et al. (2007) further notes that NAADS appears to be encouraging farmers to diversify into profitable new farming enterprises than focus on increases in productivity.

With regard to the profit function, results in Table 6 show that increased farmer expenditure on fertiliser and traction power had no significant effect on gross profit - although the coefficients were positive and of similar elasticity magnitude as in the yield function. Also, increased farmer expenditure on other improved inputs including seed, herbicides/fungicides and manure had no significant impact on gross profit though positive. Non-significance of these variables may be associated with the minute proportion of farmers in the sample using these inputs compared to non-users.

Although increase in the area cultivated was found to negatively influence yield, on the contrary it was found to be the single most important physical input in increasing the gross profit. Controlling for other factors, the elasticity indicated that farmer increase in area cultivated by 1 hectare was likely to increase their gross profit by 83 percent. This finding, which is consistent with Demircan et al. (2006) is most probably due to the economies of scale arising from the normally rapid decline in average fixed costs as well as average variable costs with increase in output –which in the case of low productivity agriculture is due to increase in area cultivated.

The coefficient of *manure cost* with regard to gross profit was negative and significant. This indicates that increased farmer expenditure on manure only reduced their gross profit. Moreover, though not significant, yield was also negatively associated with increase in expenditure on manure. Irrespective of other factors, this result suggests the economic returns from manure application were much lower than the cost of the input.

The result concerning *household size* suggests that farmers with larger families were associated with lower profit inefficiency. This result was statistically significant at less than 5% level. Kolawole (2006) and Bravo-Ureta and Pinheiro (1997) are some other studies that also report a positive correlation between household size and gross profit. Since family size and family labour use are closely related, it probable that farmers with large families used more of family labour and less of hired labour and even may be traction power, hence saving on production costs.

The coefficient linking farmer *education level* and profit was negative and statistically significant –implying that farmers with lower profit inefficiency were associated with higher levels of education. Others studies including Kolawole (2006), and Hyuha et al. (2007) also got similar results. With regard to the link between farmer profit and access to extension services, the coefficient of was highly negative and statistically significant. Several other studies, including Kolawole (2006), Hyuha et al. (2007), Rahman (2003), Bravo-Ureta and Pinheiro (1997) and Ali and Flinn (1989) have also posted similar results. The reason is that farmers who have access to extension services are likely to have better agronomic skills that may enable them produce higher output by operating at a higher level of efficiency.

The last variable in the profit function to report on is *age* -whose coefficient was negative and statistically significant. This result implies that older farmers obtained more profit than their younger counterparts. Since age was found not to have a significant effect on yield, it is most likely that older farmers -who usually have larger families, most probably utilised family labour thereby significantly reducing labour-related production costs and hence increasing gross profit.

6.0 CONCLUSIONS AND IMPLICATIONS

This paper examined the physical and economic productivity of improved inputs used by smallholder maize farmers in Uganda. In addition, the relationship between farmer characteristics and productivity was also examined. The Maximum likelihood technique was used to estimate both the yield and the gross profit -modelled as stochastic frontier functions. One of the key findings of this paper was that while use of improved inputs such as seed and fertiliser significantly boosted yield, the marginal cost of improved inputs was much higher compared to the additional revenue from the increased output associated with improved inputs use. Moreover, among the eight seed-fertiliser input-mix production practises assessed in maize cultivation, farmers who used home-saved improved seed variety without fertiliser obtained lower yield but the highest gross profit. Furthermore, when the opportunity cost farmer's own land and family labour inputs in maize production were imputed, the farmer's net profit was highly negative especially in the western and central regions of Uganda. This finding points to the importance of examining not only the physical but also the economic returns when assessing the likelihood of farmer adoption of new technologies and/or use of own resources in production. Based on the prevailing farmers' production technology, cultivation in the range of 2-3 ha appeared to provide optimum profit while cultivation under 1 ha and above 4 ha led to economic losses.

Econometric results confirmed the inverse relationship between farm size and yield, but showed that increase in area cultivated was one of the few physical inputs to increasing smallholder gross profit. Also, the results showed that farmers with more household members were associated with higher levels of yield and gross profit. An important conclusion from these results is that increase in area cultivated –particularly own land and use of family labour appeared to be main inputs sustaining maize farming in Uganda. Thus, at the prevailing state-of-the-art technology of maize production and market conditions, it is apparent that maize farming in 2005/06 was of no economic consequence to the nation. Since state-of-the-art of maize production and market conditions that prevailed in 2005/06 have more or less not changed to the better, the economic significance of maize farming in Uganda may as well be at the status-quo of 2005/06.

Farmer access to extension services was one attribute that was found to be significantly associated with higher yield and gross profit, despite the fact that less than 10 percent of the farmers received these services. This result illustrates the importance of government investment in extension services provision as one of the effective measures to increase farmer efficiency. Concerning the likely impact of farmer dependence on rainfall, the results suggest that this had significant effect on yield but not gross profit -as lower farmer output was likely to be offset with higher prices arising from higher demand.

Results of this paper should be of interest to Uganda's policy-makers -especially those implementing the NAADS programme, where maize cultivation is one of the widely supported enterprises especially in eastern Uganda, as well as to policymakers who are soon to implement the maize component in that revised DSIP. As no remarkable productivity-enhancing changes have been registered in agriculture for the past 5 years (MFPED, 2009), it can be concluded that at household level, use of improved inputs in maize farming still yields sub-optimal gross profit given that input prices have risen as equally as output prices and, the net benefit of maize farming is still negative.

As with any research, this study was subject to some limitations. First, the present study was based on cross-sectional survey data. Farm-level panel data was not utilised, as it was not available. Analysis based on cross-sectional data lacks of capability to track the dynamics of farmer performance over time. In the near-future however, it will be possible to undertake farm-level panel-data analysis in agriculture. This is because UBOS has started collecting this data. Second, this study focused on maize only. It is possible to do a similar level of analysis for other crops, such as beans or sesame. It is also entirely possible to include more than one crop or even livestock in the analysis. That is multi-commodity analysis -which is realistic in smallholder farming. The only limitation with such analysis is availability of complete data.

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