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Determinants of technical efficiency in smallholder soybean production in Bomet District, Kenya

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Increased soybean productivity has great potential for alleviating the perpetual problems of food and nutrition insecurity, poverty and unemployment among the rural households in Kenya. This study analyses the determinants of technical efficiency in smallholder soybean production in a rural farm setting in Bomet District, Kenya. Technical efficiency in this case is the ability of the smallholder farmer to maximize soybean output from a given level of inputs including seed, fertilizer, crop protection chemicals and labour. The primary data used was collected from a field survey using a multistage random sampling design, with the sampling being done at division, location, sub-location and household levels. A structured questionnaire administered in a face to face interview on a proportionate sample of hundred soybean farmers was used. Stochastic Cobb- Douglas frontier model was used to estimate technical efficiency levels while an inefficiency model was used to examine inefficiency variables. Education level, occupation, age and gender affected technical inefficiency. Education level and occupation had negative effects while age and gender had positive effects on inefficiency. Hence, policies targeting promotion of farmer education and farming professionalism would lead to significant increase in the level of technical efficiency in smallholder soybean production.

Key words: Determinants, Stochastic Cobb-Douglas frontier model, technical efficiency, small-holder, soybean, Kenya.

INTRODUCTION

Soybean was introduced as a commercial oilseed crop to Kenya around 1904 (GoK). It was however not until early sixties when the cultivation started in earnest on small-scale in Nyanza and Western provinces and by large scale farmers in Trans-Nzoia, Uasin Gishu, Laikipia, and Nakuru Districts (GoK, 2009) and is now concentrated in Western, Nyanza, Rift Valley, Eastern, and Central, where it is produced for food and nutrition security, and as a source of income. Western province is the leading producer, accounting for over 50% of total national smallholder planted area and production followed by Nyanza and Central provinces (GoK, 2009). However production and yield have stagnated since 1990 at 2000 metric tons year^{-1} and 800 kg ha^{-1} respectively (FAO, 2008) while demand for soybean and its products is currently over 150,000 MT year^{-1} (Thagana and Riungu,

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2000; Jagwe and Nyapendi, 2004). The resultant widening deficit is met by importation with vegetable oil and fat imports alone totalling Ksh 23.3 billion in 2007 (GoK, 2009).

The unexploited national annual production potential of about 300,000 MT (GoK, 1985) and the productivity potential of about 2600 kg ha^{-1} (KARI, 2005; Ministry of Agriculture, 2007; Thagana and Riungu, 2000) reveal the existence of enormous potential. The production can be enhanced through vertical (productivity) and horizontal (area) growth. But considering the limiting land resource which is becoming exhausted, emphasis is placed on increased productivity through use of improved production technologies which efficiently utilise the available productive resources. Several soybean production technologies including improved varieties, crop management and protection techniques have been continuously generated by agricultural research system and disseminated to the farmers for enhancing productivity and profitability. However, the benefit associated with such technological advancement has not been fully enjoyed by the smallholders. The escalation of inputs costs especially fertilizers, diesel, crop protection chemicals and land rent in Kenya has become prohibitive to realization of the benefits. It is therefore important to make serious economic consideration when evaluating production technologies before being recommended for use by the farmers, rather than just evaluating for technical potential. Any technological recommendation must therefore be targeted at specific socio-economic circumstances of the farmers. Farmers usually choose and use technologies that are within their technical and economic capacities.

Resource-use efficiency measures are important indicators of the viability of any agricultural activity and hence the economic performance of any technology and producer. The efficiency levels can be used to select the most cost-effective input use options and to determine the magnitude of gains that could be obtained by improving efficiency of the existing production technologies. This can provide the farmers with criteria for adjusting the levels of inputs use for maximizing benefits. This study tried to address the factors explaining the huge mismatch between the production (supply) and demand for soybean and its products among smallholders in Bomet District, Kenya. The general objective of the study was to establish technological sources of inefficiency in smallholder soybean production in a rural farm setting in Kenya so as to find feasible ways for increased productivity and farm income. The specific objectives were to determine the efficiency levels of resource use in smallholder soybean production and establish factors that influence efficiency levels in smallholder soybean production. This would help isolate those factors that are constraints to technological efficiency in smallholder soybean production in the study area.

METHODS AND MATERIALS

The study was carried out in Bomet district, Bomet County, Kenya. The District was chosen for this study because soybean cultivation has been promoted, by various stakeholders which include KESA, KARI and Ministry of Agriculture (Extension service), over the last decade to assist the smallholder farmers in the District to alleviate perpetual food and nutrition insecurity and poverty. Bomet District is one of the forty-two districts of Rift Valley Province and centred at latitude 0° 29' and 1° 03' South and longitudes 35° 05' and 0° 35' East with an area of about 1450 km^{-2} and 443,640 residents with 419 persons km^{-2} increasing at 2.6% $year^{-1}$ (GoK, 2002). Most farmers are small-scale with an average farm size of 2 ha (GoK, 2008).

Primary data was used in the study and was collected from a field survey conducted in the District. A multistage simple random sampling technique was used to select the sub-locations, the primary units from which a sample of 100 farmers were drawn. The data was obtained from the sample farmers using a structured questionnaire that was administered to the sample soybean farmers in face-to-face interviews by the researcher and the locally selected and trained enumerators.

Empirical model

Stochastic Cobb-Douglas function model was chosen because of the variability nature of agricultural production and smallholder farmers. The stochastic frontier method makes it possible to estimate a frontier function that simultaneously takes into account the random error term and the inefficiency component to every farmer. The stochastic Cobb-Douglas production (CD) function used was of the following form:

$$Y = a_0 X_1^{a1} X_2^{a2} X_3^{a3} X_4^{a4} X_5^{a5} e^{E} \quad (1)$$

Where: Y is soybeans yield($kgha^{-1}$), a_o = an efficiency parameter, and; X_1, X_2, X_3, X_4, X_5, are farm-level soybean production related attributes including land ($hayear^{-1}$), labour ($m.dsha^{-1}$), seed ($kgha^{-1}$), fertilizer ($kgha^{-1}$) and crop protection chemicals ($kgha^{-1}$) invested, $a_{1...}$ a_5= regression co-efficient (unknown parameters for the respective inputs – X_1, X_2, X_3, X_4 and X_5)

E = random disturbance term (error term) – accounts for the unpredictable variation in output due to such variables as the weather, but also include v and u, or the stochastic and inefficiency components of the error term respectively).

All the variables were examined, prior to estimation of the function (model), for multicollinearity by using Klein's Test (Debertin, 2002; Sankhayan, 1988). The Stochastic Cobb-Douglas production frontier was estimated using the maximum likelihood (ML) estimation techniques (Sankhayan, 1988; Kiresur et al., 1993). Variables that affected the smallholder soybean farmers' technical efficiency were assessed using the inefficiency model specified by Battese (1992), and Coelli (1995), as shown in Equation 2:

$$u_i = \alpha_o + \sum_{i=1}^{n} \alpha_i z_i + w_i \quad (2)$$

Where u_i is the inefficiency measure, Z_i is a vector of socio-economic factors affecting inefficiency which include: age (yr) and education level (yr in school) of the household head; adults per household (15 years and above); household head experience in farming (yr); farm size (ha); farm income ((Ksh)); extension contact (visits yr^{-1} paid by extension agents); gender of the household head (1 if male; 2 otherwise); access to credit (1 if access; 0 otherwise);

Table 1. Estimates for stochastic frontier production function of parameters of soybean per unit of inputs in Bomet District, Kenya.

Production factors	Coefficient of regression	Standard error	P-value
Constant	7.6856	0.4433	0.0000
Soybean farm area	0.1031	0.0494	0.037**
Labour	-0.1815	0.0925	0.050**
Seed	-0.0225	0.0561	0.689
Fertilizer	0.0167	0.0076	0.029**
Agrochemicals	-0.0165	0.0362	0.649

** (p<0.5), Summarized from computer output (STATA).

occupation of household head (1 if farming is major occupation; 0 otherwise); organization membership of household head (1 if member of a cooperative or farmer group, 0 otherwise.

RESULTS AND DISCUSSION

In the stochastic production frontier model, inputs used for soybean production were land, labour, seed, fertilizer and agrochemicals. Soybean land area, labour and fertilizer affected technical efficiency (Table 1) and soybean area and fertilizer quantity were positively related to soybean yield.

The findings about farm size concurs with those of Umoh (2006) which indicated a positive relationship between soybean area and technical efficiency and that farm size would not only have a direct effect on production but also an indirect effect on output through the marginal productivity of non-farm inputs. This was supported by recent studies by other researchers like Otitoju and Arene (2010) who found land to have a positive and significant association with soybean output under medium-scale production in Benue State, Nigeria.

The significant positive coefficient of fertilizer shows that application of optimum level of fertilizer increases the output by enhancing the productivity of soybean. This concurs with Huyuh et al. (2008)'s findings which found that a 1% increase in fertilizer rate could cause nearly 36% increase in soybean output. Increased use of chemical fertilizers would therefore assist the smallholders compensate for the limiting land resource. However, this requires judicious and optimal usage for increased productivity and profitability.

The estimated coefficient of household labour was negative. This implies that any additional use of labour by the soybean farmers would decrease the technical efficiency by increasing the cost of production thus affecting profitability. Though not expected on priori ground, the results concur with those of Kiresur et al. (1993) which found a significant negative coefficient in India's oil crop production. The negative effect of the household labour variable could have been due to the fact that smallholder soybean production in the area is labour-intensive right from land preparation to harvesting, and therefore for optimum yield to be realized, high cost of labour is required (Ajibefun and Aderinola, 2003). These were further supported by Otitoju and Arene (2010) who found labour variable to be significant with a negative coefficient and that any additional use would result in a decline in marginal productivity.

The estimated coefficients of both seed and agrochemicals were not statistically significant hence soybean productivity was independent of seed and agrochemicals rates. This was contrary to the *a priori* expectation and some past studies by Oyewo et al. (2009) and Huyuh et al. (2008). In Bomet District, the insignificant effect of seed on the productivity of soybean could be attributed to the type of seed the farmers were using.

Determinants of technical inefficiency

The sources of inefficiency were examined using the estimated coefficients associated with the inefficiency variables specified in the inefficiency model (Equation 2). The variable considered included farm size, age, gender, occupation, number of adults, credit access, membership to organization, level of education and extension contact (Table 2).

Older compared with younger household heads were more inefficient in soybean production agreeing with Owuor and Ouma (2009) who found that younger farmers were more efficient than the older because they were more adaptive to modern farming technologies but contradicting other findings (Onu et al., 2000; Amaza and Olayemi, 2000; Faturoti et al., 2006) which found older farmers to be more efficient due to more farming experience which enabled them to acquire knowledge and skills necessary for choosing appropriate new and improved production technologies. The age disadvantage is of concern as only 26% of the soybean farmers were of 21 to 40 years.

Male compared with female headed households were more inefficient in soybean production (Table 2). This is

Table 2. Regression results of factors explaining soybean production inefficiency.

Inefficiency factors	Parameters	Coefficient of regression	Standard error	P-value
Soybean farm area (Ha.)	∂_1	-0.2430	0.1661	0.144
Occupation of H/H(0,1)	∂_2	-3.1347	0.6042	0.001*
Gender of the H/H (0,1)	∂_3	0.0603	0.4455	0.049**
Education level of h/h (0,1,2,3,4)	∂_4	-0.5000	0.2881	0.038**
Number of adults (No.)	∂_5	-0.2983	0.1725	0.065
Age of household head (years)	∂_6	0.0534	0.0242	0.027**
Extension contact (0,1)	∂_9	-0.0628	0.2750	0.819
Credit access (0,1)	∂_{10}	-0.7994	0.7587	0.460
Membership to organization(0,1)	∂_{11}	-0.7192	0.6797	0.290
Diagnostic statistics				
Log likelihood	1.5014			
Sigma v		0.0008	0.0026	
Sample size = Population	100			
Wald chi2 (6)	205787			
Prob > chi2	0.0000			

** (p<0.05) * (p<0.1), Summarized from computer output (STATA).

of concern as 70% of the households in Bomet District were headed by the males. These results contradict Otitoju and Arene (2010) who showed that male- compared with female-headed households were less technically inefficient

When the main or only occupation of the household head was farming, technical inefficiency of soybean production was less compared with otherwise. This implies that more time for management improves technical efficiency confirming Ojo's (2003) conclusion that farmers should be encouraged to use more time to supervise their farms so as to improve their technical efficiency.

Increased education reduced technical inefficiency among the farmers. The findings conform to *a priori* expectations and concur with Oyewo et al. (2009) that farmers with more formal education tended to be more technically efficient in maize production in Oyo State of Nigeria.

The coefficient of the number of adults in the household had negative sign but insignificant. This indicates that the variable had no influence on technical inefficiency or efficiency meaning that households with larger number of adults were no more efficient or inefficient than households with smaller numbers. The reason may be that the available family labour was not being used or utilized wholly in the production of soybeans. The results were inconsistent with Onyenweaku et al. (2005), which identified a positive relationship between household size and technical efficiency among crop farmers. Villano and Fleming (2004) also found a significant positive coefficient for number of adult persons in a household and indicated the more they were, the more quality labour would be available for carrying out farming activities in timely fashion, thus making the production process more efficient.

Credit access, membership to organization, extension service and farm area did not affect technical inefficiency. These findings did not conform to *a priori* expectation of negative and significant effects on technical inefficiency. Earlier studies gave varied results. Huyuh et al. (2008) found no effect of credit access but available land area was negatively related to technical inefficiency. Ogundari and Ojo (2007) found that credit access reduced technical inefficiency for small scale food production in Nigeria.

CONCLUSIONS AND RECOMMENDATIONS

The study revealed that the smallholder soybean farmers in Bomet District of Kenya have a wide scope for improvement just with the existing production technologies. Land (farm area) and fertilizer were the main direct input of production that had significant positive influence on technical efficiency while labour had significant negative effect making it the single main input contributing to low efficiency in smallholder soybean production in Bomet District. Occupation and education level of the household head tended to reduce technical inefficiency or invariably increase technical efficiency level among soybean farmers. On the other hand, age and gender tended to increase technical inefficiency effectively reducing the farmers' level of technical efficiency.

Improvement in productivity among the smallholder soybean farmers in Bomet District could be achieved by addressing some of the important policy variables that negatively and positively influenced the farmer' levels of technical efficiency. Since education level and occupation of the household head negatively influenced inefficiency, policies targeting improvement of farmer education and farming professionalism are recommended. These would include engaging young educated people in farming, training relatively old people through informal education like in Agricultural Training Colleges (ATCs) where they would be trained specifically on crop husbandry aspects like choice of seed and varieties, and crop management and protection.

The farmers should be encouraged and trained on some aspects of farming economics like proper allocation of available resources and judicious use of farm inputs given their rising prices. The government needs to formulate policies that are favourable to smallholder farmers especially in regards to accessibility of affordable farm inputs and appropriate labour-saving technologies such as soybean threshers and herbicides considering that soybean production is labour intensive. The farmers should also be encouraged and facilitated to form and join organizations like self-help groups and cooperative societies. Since age and gender tended to increase technical inefficiency, strategies should be developed that will not discriminate farmers on the basis of these variables in soybean production. Older farmers should be encouraged to involve female and youth in the handling of productive resources.

Conflict of Interest

The authors have not declared any conflict of interest.

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