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Factors Affecting Technical Efficiency of Beans Production among Smallholder Farmers in Rwanda

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ABSTRACT

Beans are still largely a subsistence food crop under promotion for a food security especially in urban areas and source of income. In a bid to attain self-sufficiency, the country made remarkable efforts to develop the subsector. These were mainly directed towards the expansion of the area under beans, organisation of farmers' cooperatives and easy access to inputs. In Improving beans productivity and marketing of beans several both public and private interventions were added in Nyanza and Bugesera districts those interventions include breeding, distributions of improved seed that are pest and diseases resistant and promotion good agricultural practices. Despite efforts put up by the Government of Rwanda and other stakeholders, beans still faces low productivity compared to the expected potential yields and the actual yield. The objectives of this study were to estimate the technical efficiency level in beans production in both Nyanza and Bugesera districts and to determine some socio-economic factors affecting technical efficiency of beans producers in Rwanda. Primary and secondary data were used. Stochastic Frontier Analysis (SFA) with the Cobb-Douglas function on a random sample of 276 beans farmers. The findings indicated that the mean technical efficiency for beans production in both districts is 23% which means that farmers can increase their output through efficient use of available resources and existing technology if they are to be technically efficient. The study concluded that age, educational level, fertilizers, labor, land size, seeds, visit of agent of extensions and access to credit were significant variables leading to technical inefficiency in Rwanda. On the other hand, family size, type of seeds, and experience, had no significant impact on farmers' efficiency. To increase technical efficiency for beans production in the Rwanda, the study recommended improvement in education level of the farmers and availability of funds in the optimum time besides on these a review of agricultural policy with regard to renewed public support to revamp the agricultural extension system, which has been neglected since long time, will be required.

INTRODUCTION

Agriculture is the most important sector of the Rwandan economy; contributing 41% of Gross Domestic Product (GDP) and employing around 90% of the Rwandan population living in rural areas [1]. Agriculture is important for sustainable development, poverty reduction, and enhanced food security, and supplies over 90% of the food consumed in the country, while manufacturing accounts for only 13% of GDP [2]. Indeed, promoting agriculture is imperative in achieving the Millennium Development goals (World Bank, 2008).

Bean is the most important crops in Rwanda [2] and comes as a first strategy to reduce poverty [3]. The Rwandan government classified bean as a priority crop for development and food security that can serve as an example to the rest of the agricultural sector of how rapid transformation can take place [3]. To promote beans, RAB has developed high yielding varieties. In recognition of the major role of beans in food security and as source of income for small holders beans growers especially in Bugesera district subsidies inputs policy was introduced since 2006.

In Improving bean productivity and marketing of bean several both public and private interventions were added in Bugesera districts those interventions include breeding, distributions of improved seed that are pest and diseases resistant and promotion good agricultural practices. Despite efforts put up by the Government of Rwanda and other stakeholders, bean still faces low productivity compared to the expected potential yields and the actual yield. The expected potential yield for the introduced varieties is 4-6 tons per ha but farmers have only realized production of up to 1.6 tons per hectare [4].

Variability in production is in function of difference in scales of operation, production technologies, operating environment and operating efficiency [5]. Production increase is not in proportional of the adoption rates of new technologies but efficient use of available technology [6]. To improve efficiency in production allows farmers to increase the output and changing production technologies resulting in increased productivity [7]. According to the same author smallholder farmers, variation in production due to difference in efficiency may be affected by various regional and farm specific socio economic factors.

To increase productivity, technology innovation is required but not sufficient, efficient use of old technology is necessary [6]. If farmers are not efficient using existing technologies then improving efficiency will be more cost effective in short run than introducing another technology. Technical inefficiency may arise primarily due to managerial incompetence and therefore and therefore efficiency differences could be explained in the context of management characteristics such as: training, experience and motivation [8].

Since increased productivity is directly related to production efficiency, it is imperative to raise productivity of the farmers by helping them reduce technical inefficiencies. This could be achieved by investigating the nature of resource productivity and efficiency in production of the farmers. Therefore, there was need to examine the technical efficiency of bean production in Bugesera District and factors affecting technical efficiency.

METHODOLOGY

The present study was conducted in Bugesera District which is situated in the Eastern Province of Rwanda with 1,334 square kilometers. The population of Bugesera district is estimated at 274,113 persons while 99 percent live in rural areas (District report, 2006). This research used both primary and secondary data. Primary data gathered from farmers through face-to-face interviews using multi-stage and pre-tested questionnaires.

Analytical framework

According to Batesse and Coelli [9], the first researchers analysing Technical Efficiency and its determinants used a two stage approach. The first stage involves the specification and the estimation of the stochastic frontier production function with the assumption that the inefficiency effects are identically distributed. The second stage of this approach concerns the specification of a regression model for the inefficiency effects. However, this approach has been subject to the criticism that it contradicts the assumption of identically distributed inefficiency effects in the stochastic frontier and Wang and Schmidt [10] identified the results biasness related to this two-step analysis.

Recently, a one stage approach has been proposed by various researchers including Batesse and Coelli [9] and Belotti et al. [11] who specifically created command syntax for the simultaneous estimation of both the stochastic and the inefficiency models parameters in Stata package. In this model, the parameters of the stochastic frontier and the inefficiency function are estimated simultaneously through the maximum likelihood estimation (MLE) method. It is noted that the one stage model by Batesse and Coelli [9] though initially proposed for panel data, its variant has been used in cross sectional data by numerous authors such as Ezeh et al. [12], Rahman et al., [13] and Tijani [14]. In the present study, same simultaneous analysis approach was used.

Model specification

To assess the determinants of bean production among the inputs used and to determine the technical efficiency levels the Cobb-Douglas function was used its simplicity and ease of estimation and interpretation. From the estimation of the stochastic frontier production function, the effects of the production inputs on bean output were obtained and statistical tests at this level revealed the significant determinants. The estimation of the inefficiency model and later the levels of TE were predicted after the estimation of the two models.

A Cobb-Douglas production function was specified as;

$$\ln Y_i = \ln\beta_0+\beta_1 \ln X_1+\beta_2 \ln X_2+\beta_3 \ln X_3+\beta_4 \ln X_4+V_i-U_i$$

where:

Yi : In of bean output (T/ha)

β_0: In Inefficiency effect

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X_1: In of total area grown to bean (ha)

X_2: In of amount of labour(man days)

X_3: In of total fertilizer used (kg)

X_4: In of total Seed used (kg)

V_i= random error related to non-included factors

U_i = random error term of measurement

The data on socio economic effect which was the last objective of this study was analyzed using Stata to obtain the maximum likelihood estimates of parameters order to estimate the technical inefficiency effects. The specification model was as follows:

$$| \mu_i | = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \alpha_7 Z_7 + \alpha_8 Z_8 + \epsilon$$

μ_i : Inefficiency

α_0 : Intercept term

Z_1 : Education level of household head

Z_2: Experience (years)

Z_3: Access to credit (Dummy: 1= YES, 2= No)

Z_4 : Age of farmer (years)

Z_5 : Household Size (numbers)

Z_6 ; Number of visits by an extension agent

Z_7 : sex of household head (Dummy 1=Male, 2 =Female)

Z_8 : Type of seed used (Dummy: improved=1 local =2)

ϵ : Random error

RESULTS

Parameters estimation of the production factors

The stochastic frontier production function results **Table 1** shows results of the stochastic frontier model from their efficiency. The results shows that results of the input elasticities for each input in the Cobb-Douglas production function. A one percent increase in the quantity of organic fertilizer applied increase bean output by 0.13% and a one percent increase in the quantity of inorganic fertilizer applied increase bean output by 0.23%. In addition, a one percent increase in improved seed rate increased output by 0.86%. On the other hand, a one percent increase in labor will probably increase bean yield by one percent.

The study shows that land is the major variable that highly responds to the yield, followed by improved seed, labor and fertilizer. The results showed that the yield responds to the land size and this explained that the most of Rwandan land is totally different in the study area.

Table 1. Stochastic frontier function results and stochastic frontier production function results.

Variables	Coeff	S.E	t -Ratio	P>t
Constant	0.35	0.35	5.73	5.73
Organic fertilizer (kg)	0.13**	0.19	0.78	0.001
Inorganic fertilize	0.23**	0.08	0.535	0.013
Improved seed (kg)	0.86**	0.16	0.42	0.014
Local seed (kg)	0.02	0.08	0.84	0.184
labor (man-days)	0.27**	0.12	0.91	0.041
land (ha)	1.16**	0.17	0.49	0.019
		Diagnostic test		
Insig2v	2.65	0.34	7.71	7.701
/Insig2u	1.77	0.38	4.65	8.625
sigma_v	0.27	0.05		
sigma_u	0.41	0.08		
sigma2	0.24	0.06		
lambda	0.155	0.10		
gamma (γ)	0.40			

Log likelihood =	-50.67			
Wald chi-square	1.18			
chibar²(0	16.19			

** and * means statistically significant at 1% and 5% a significance level. Source: Computed by author based on Smallholder Farmer Survey, 2011.

Technical efficiency levels among bean farmers

In determining the technical efficiency of bean farmers in Musanze and Bugesera districts results showed that the technical efficiency minimum level was 18 to technical efficiency maximum 79% while mean technical efficiency was 23% as it is indicated in **Table 2**.

Table 2. Frequency distribution of technical efficiency estimates.

Technical efficiency Range (%)	Freq.	% of Total
0-25	143	51.81
26-50	73	26.45
51-75	32	11.59
76-100	28	10.15
Total	276	100
Mean TE	23%	
Minimum TE	18%	
Maximum TE	79%	

Source: Computed by author based on Smallholder Farmer Survey, 2011.

The results also indicated that nearly 11.59% of the farmers had over 51-75% technical efficiency. Majority of farmers 51.81% were recorded a technical efficiency of 0-25% with the lowest portion followed 26.45 ranged between 26-.50 only 10.15% of the farmers had 76-100% TE. The wide variation in technical efficiency estimates is an indication that most of the farmers are still using their resources inefficiently in the production process and there still exists opportunities for improving on their current level of technical efficiency.

Inefficiency models results

In the assessment of factors affecting TE, the variable age of farmer, household size, education level of the farmer, bean, bean farming experience, use of credit in and the number of visit by an extension agent to farmer were considered and regressed to the error term (u) representing the technical inefficiency. Thus, the results in the **Table 3** show the relationship between those factors and technical inefficiency.

Table 3. Inefficiency effects model.

Variables	Coefficient	Stand Error	t	P>t
Constant	-1.76	1.32	0.91	0.98
years of Education for the farmer	- 0.24**	0.018	13.00	0.013
Experience (Number of years of experience in farming)	0.037	0.021	0.53	0.599
Credit access, Dummy variables (1=has access 0 = NO)	- 0.08**	0.049	1.71	0.028
Family size (numbers)	0.006	0.004	1.41	0.158
sex of household head 1=male,2=female	-0.007	013	0.53	0.595
extension services 1=yes 0=no	- 0.124**	0.0134	2.29	0.026
Age (years)	- 0.042 **	0.008	5.38	0.000
Type of seed	0.061	0.049	1.27	0.207
Log likelihood	21.84			

** and * means statistically significant at 1% and 5% a significance level

Source: Computed by author based on Smallholder Farmer Survey, 2015.

The results in **Table 3** reveal that, the number of years in school, access to credit, age and extension service contact reduce technical inefficiency or increase technical efficiency.

The negative sign on the years of school indicates that an increase in the number of school years decreases technical inefficiency which means that as years of school increases technical efficiency; this relationship is significant at both 1% and 5% level. However, the quadratic structure of age is positive implying that farm technical efficiency increases with an increase in the number of school years of the farmers.

The role of education enables farmers to understand the socioeconomic conditions governing their farming activities and to learn how to collect, retrieve, analyse and disseminate information. Moreover, with higher levels of education, farmers are able to organize themselves into farmer groups or associations, thereby enabling them to source funding from lending institutions, especially from non-government organizations (NGOs) engaged in micro credit delivery. Education also enhances farmers' understanding of extension recommendations.

DISCUSSION

Determinants of bean production

The first hypothesis corresponds to the second objective that aimed at identifying the determinants of bean production in the study area. For this the study the considered inputs used in bean production was seed quantity, fertiliser, land size and labor. Moreover, the study hypothesized that all of those factors were significant in the production of bean. Results in **Table 3** confirm this hypothesis.

From those results, the land size was revealed to be the most important inputs in the production of bean for both studied schemes. Based on the signs of coefficients, the input was found positive and significant at both 1% and 5% level in the study area. These findings also revealed that farmers are currently operating below the optimal land scale in bean production as the increase in area under bean would lead to higher output quantity and farmers would thus benefit more from bean production by increasing land size under the crop.

The results on the relationship between land size and bean production in this study were consistent with the findings by Tijani [14] in his analysis of technical efficiency of bean farms in Osun-Nigeria, Khan et al. [15] on bean farming in Bangladesh, and Baruwa and Oke [16] in their study on cocoa yam in Nigeria. On the other hand, these results were in contradiction with the findings by Chirwa [17] which revealed that land size had negative influence on bean yields in Malawi. In the latter study, negative effect was explained by operating beyond the optimal land scale where the production was being done on larger lands than what farmer could manage. Thus, in Rwanda, the size of bean farms is still manageable, and the area expansion would contribute in increasing the production. However, this expansion should be done carefully as some studies have found that land size may inversely increase with TE [18]. Moreover, the country's reality about the arable land scarcity should not be ignored. Thus, supporting measures like using improved technologies should rather be considered instead of relying on land size.

Besides on land size other factors such fertiliser, the amount of seed and the labour used in bean farming activities were found significant to bean production in the study area **(Table 1)**. Thus, if the findings showed that all inputs were significant at both 1% and 5% levels **(Table1)**. The conclusion was that all the inputs used in the production significantly determine the bean output in the study areas.

Technical efficiency levels

According to Coelli et al. for the half-normal and the exponential models, the null hypothesis about the absence of inefficiency effects involves one parameter often noted as sigma ($\sigma\mu$). The parameter represents the variance related to the inefficient effects in the stochastic frontier model. As the variance of the inefficiency effects is concerned, Batesse and Coelli [9] specified another parameter gamma (γ) which is associated to the two error terms of the stochastic frontier functions. The parameter γ measures the output deviation from the frontier caused by inefficiency effects and it equals to $\sigma 2\mu/(\sigma 2v + \sigma 2\mu)$ where $\sigma 2\mu$ and $\sigma 2v$ are respectively standing for the variances related to inefficiency and statistical noise. In this study, γ value was found different to zero being respectively 0.40 and this values thus indicated that 40 % of the variations in output were caused by inefficiency effects.

Findings in **Table 1** showed that the calculated chibar-squared values (χbar2) for the estimated models exceeded the critical values from the statistical table. This led to the rejection of the second hypothesis. Hence, there are significant inefficiency effects in bean production in Bugesera and the farmers have not yet attained the production frontier.

Factors influencing technical efficiency

The results in **Table 1** showed that this hypothesis was rejected based on the value of chi-statistics which exceeded the critical values. This led to the conclusion that the joint effect of the seven variables is significant though some individual influence may not be statistically significant.

The analysis of socio- economic factors effects on TE, several of them were found significant. For instance, age, the number of years in school, access to credit and extension service contact reduce technical inefficiency or increase technical efficiency. This implied that age had a negative influence on TE; an increase of age by 1% would lead to 0.042% increase in inefficiency effects. This also indicated that the older a farmer was, the lower the technical efficiency in bean production and the lower the productivity.

The negative sign on the years of school indicates that an increase in the number of school years increases technical efficiency; this relationship is significant at both 1% and 5% level. This finding is related to those reported by Awudu et al. in their study on technical efficiency during economic reform in Nicaragua found that education increases production efficiency). A study by Seyoum et al., [19] on technical efficiency and productivity of bean producers in Eastern Ethiopia concluded that farmers more educated adopt rapidly the new technology and produces closer to the frontier output.

In the inefficiency model, various researchers discussed that the variable age may take either a negative or a positive sign [10]. Age may take a negative sign when older farmers are willing to adopt better techniques reducing inefficiency effects or when the knowledge and the experience acquired over their farming years contribute in increasing efficiency. It may also take a positive sign like in this study, indirectly indicating that older farmers resist to the adoption of new technologies or/and they do not have physical and mental capacity to efficiently participate in farming activity. This could be the case for bean farmers in Rwanda as long as the positive effect of labour in production has been found significant.

In this study education level was found having a negative significant effect on technical inefficiency implying that it has positive relationship with technical efficiency. This meant that the more farmers are educated on the appropriate methods of farming as well as resource use the higher the level of technical efficiency. Bean related trainings or education level of farmers to farmers could allow them to access innovative and up to date production techniques. It could also increase pioneer spirit in agricultural technology adoption, thus better decision making in production process.

The findings on education level are similar to those about the extension agent's visits which revealed a negative and significant relationship between number of visits and technical inefficiency among bean farmers in Rwanda. This indicated positive relationship between extension contact times and technical efficiency. This implied that the visits of the extension officers to bean farmers contribute to TE in bean production. The positive relationship between technical efficiency and extension contacts frequency could be attributed to knowledge and information that bean farmers receive which is complementary to the trainings.

Regarding the access to extension services, the findings of this study were consistent with those of Seyoum et al. [19] in their study on gender differentials in technical efficiency among bean farmers in Nigeria. Nchare and Muhammad-Lawal et al. [20] found the same relationship respectively in their studies on Arabica coffee production in Cameroon and technical efficiency of youth participation in agriculture. In contrast, Tijani [14] and Ezeh et al. [12] found out that extension contact had an unexpected negative relationship with TE and they recommended further investigations on the issue.

Finally, results showed that the gender was negatively affecting technical inefficiency then contributing to TE though not significantly. Bean farming experience and family size were found positive but insignificantly affecting technical inefficiency.

CONCLUSION

The study found that despite the long history of government investment in the agriculture sector through extension services and promotion of technology, smallholder bean farming remains uneconomic and technically inefficient. TE of bean farmers varied due to many factors that change technical efficiency which lead to a decrease of bean production. Thus, there is a great chance for farmers to increase their level of efficiency in bean production.

As the number of years in school, squared number of years in school, access to credit, age, squared age, extension service contact and squared experience of operators were significant variables greatly influencing TE of bean growers. Therefore, agricultural policy makers need to look for alternative means of strengthening the socio and economic basis of bean producers in order to address resources constraints and low productivity in bean production in the study area.

Finally, since an increase in age would lead to a decrease of efficiency levels in bean production, these results call for policies aimed at encouraging the youths who are agile and stronger to grow bean and those policies would make the youths to return to the land and take up bean farming would yield positive dividends economy in particular of the study area and Rwanda in general.

Above discussed results indicate: First, there is need to promote government policy of subsidizing inputs among smallholder bean farmers. Second, there is need to enhance that improvement in provision of agricultural credit to smallholders with extension services are likely to lead to improved smallholder technical efficiency.

Other policy implications drawn from the results include a review of agricultural policy with regard to renewed public support to revamp the agricultural extension system, which has been neglected since long time. For all these to take place, it is high time that agriculture sector receive due attention and input from the government so as to advance the country's objectives of growth and poverty reduction.

The study set out to provide estimations of technical efficiency levels of bean producers in Rwanda and to explain why those variations technical efficiency among farmers in relationship with socio-economic variables.

RECOMMENDATIONS

Given that the results of the study showed that technical efficiency was significantly influenced by extension contact, access to credit, level of education, and age but also inputs (seeds, fertilizers, labour and land) then policies targeting these variables among others might have a positive impact on small scale bean production and productivity.

For government and other agencies:

1. To increase technical efficiency, the contact between extension officers and the farmers should be intensified. Therefore, policy makers should focus on pioneering effective institutional arrangements that would enhance extension access

by farmers through deployment of participatory methods such as lead-farmer model, use of group training approach; farmer-driven extension demand and or intensification in the use of the extensive mass media available in the regions that would supplement and complement the efforts of the few extension workers.

2. The positive influence of access to credit used on technical efficiency provides a basis for provision and use of credit. The high initial capital consumption and running costs by bean farmers can be provided through credit where farmers are unable to raise the required funds. Such funds included inputs costs. Therefore, credit access should be enhanced to increase use for those farmers and the government should probably influence borrowing rates on credit and loans for agricultural development because currently those rate are still high.

3. Based on the findings of this study emphasis on both formal and informal education would have a huge impact of attaining higher efficiency levels in bean production. However, since there are some farmers who have not acquired formal education and its impact is not immediate, therefore, provision of non-formal agricultural education could supplement or complement formal education. This can be done through regular training of farmers, farmer forums and on-farm practical demonstrations. The education should range from input access and use of inputs efficiently.

4. Most important findings of this study reveals that determinants of inefficiencies are the fragmented structure of farm land. Therefore a comprehensive land consolidation plan may help to increase bean production and hence improving efficiencies.

5. This study only evaluated the technical aspect of production efficiency of bean production. From the study, overuse and underuse of production factors was evident. Therefore, the study recommends an assessment of allocative efficiency of bean farmers in Rwanda. This would avail information on optimal levels of inputs use by farmers specifically on how to choose and employ the inputs in the bean production to the level where their marginal returns equals their factor prices.

For further research:

1. To identify the external factors that would indirectly affect bean production in Rwanda such as linkages to market and policy environment. The future research should analyse the bean value chain to shed the light on possible gaps in the whole process of bean production.

2. To assess the level of losses that occurs at farmer level. This study only involved the inputs-output relationship and the farmer characteristics. However, postharvest losses at farm level may reduce the final output to be sold.

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