A Nonparametric Efficiency Analysis of Bean Producers from North and South Kivu

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Introduction

The common bean (*Phaseolus vulgaris*), a major crop in eastern and southern Africa, is considered to be the world's most important food legume (HarvestPlus, 2006). In Africa, beans are an important food for people of all income levels and the primary source of dietary protein for people in the lower income bracket (Wortmann et al., 2004). Given that beans are a staple of more than 300 million diets worldwide, biofortifying the bean potentially could lead to significant improvements in the health and well being of many people (HarvestPlus, 2006).

In Africa, the majority of beans are grown by small-scale farmers in eastern Africa who have limited resources and produce the crop under unfavorable conditions (e.g., little use of inputs, marginal lands and intercropping with competitive crops). Beans are typically grown for household consumption with a small percentage sold at a market or through other venues (Wortmann et al., 2004). For the purpose of this research, we will examine the efficiency of small-scale farmers in two provinces, North and South Kivu, in the Democratic Republic of Congo (DR Congo) for producing two different varieties of beans: bush and climbing beans. We are interested in determining if there are differences in efficiency between (i) North and South Kivu producers; and (ii) climbing bean and bush bean producers. Results from the study will provide insight into how factors such as geographical characteristics and managerial decisions affect efficiency scores of these bean producers. In addition, these results can help develop appropriate and effective policies to help improve the agricultural sector in DR Congo.

In general, the soil in North Kivu is more fertile than that of South Kivu soils. North Kivu's landscape consists of rich volcanic soils while South Kivu is characterized by red clay-like soil (Dalton, 2008). Because of the higher soil fertility, small-scale farmers in North Kivu are expected to be more productive than their counterparts in South Kivu.

Traditionally, the climbing bean is a more productive crop than the bush bean (Wortmann, 2001). Correspondingly, the majority of research and development to date has centered around improving the productivity and nutritional value of the climbing bean. In East and Central Africa, the climbing bean has yields that are almost triple that of the standard bush bean (HarvestPlus, 2006). In comparison to other standard bean varieties, the climbing bean has a better heat tolerance and contains about 40% more iron (HarvestPlus, 2006). Given that the climbing bean is more productive than the bush bean, small-scale farmers prefer the climbing bean over the bush bean (Wortmann, 2001). Compared to the bush bean, the climbing bean is less susceptible to disease and more efficient in using available soil nutrients and water. Despite its advantages, the climbing bean is not typically grown in South Kivu and instead, the bush bean, which is native to the area, is grown there. Given the benefits of the climbing bean, we hypothesize that farmers producing climbing beans are more productive than bush bean producers.

Research involving the measurement of efficiency of agricultural production is plentiful in agricultural economics literature. Both parametric and nonparametric methods can be used in the analysis of the efficiency measures, but each method has advantages and disadvantages. Wadud and White (2000) suggest that the decision to use one method over the other depends on the study objective, the data available and the researcher's personal preference. According to Resti (2000), there is no clear advantage for using one method over the other. However, results from empirical studies have indicated that the type of methods can impact the estimated technical efficiency scores (Bravo-Ureta et al., 2007). In their meta-regression analysis, Bravo-Ureta et al. (2007) discovered that the estimated mean technical efficiency generated from stochastic frontier models is lower than the mean technical efficiency estimated from non-parametric deterministic models. The advantages and disadvantages of these methodologies will be discussed later in this paper.

Another issue surrounding efficiency measures is that empirical analysis of smallholder farmers does not always control for environmental production conditions that are for the most part exogenously determined (Sherlund, Barrett and Adesina, 2002). Even though controlling for these environmental factors is important in determining accurate efficiency scores, it is beyond the scope of this paper. The main focus of this paper is calculating an efficiency measure of bush and climbing bean producers in North and South Kivu and identifying factors that influence field efficiency. The specific objectives of the paper are to (1) compare mean efficiency scores between bean producers in North and South Kivu; (2) compare mean efficiency scores between climbing bean producers and bush bean producers; and (3) determine which field and household characteristics are correlated with the field's efficiency score. Our main hypotheses are (i) North Kivu bean producers have higher mean efficiency scores than South Kivu producers; and (ii) climbing bean producers have higher mean efficiency scores than bush bean producers.

This paper uses a cross-sectional data set of bean farmers in the North and South Kivu provinces of the DR Congo to examine the efficiency of climbing and bush bean production. Due to the civil unrest experienced within DR Congo, little research has been published from the country in recent years. In this study, a nonparametric method, based on linear programming, is used to analyze climbing and bush bean production efficiency. Efficiency is measured in terms of pure technical efficiency.

Literature Review

Efficiency measures can be obtained through the use of a stochastic, parametric approach or a nonstochastic, nonparametric approach (Varian, 1984; Chavas and Cox, 1988: Chavas and Aliber, 1993; Featherstone, Langemeier, and Ismet, 1997). In parametric approaches, the functional form is assumed, and econometric methods are used to estimate the flexible functional form. Production efficiency is based on the measured distance between the observations and the estimated functional form (Featherstone, Langemeier, and Ismet, 1997). According to Varian (1984), the parametric form "must be taken on faith" since the real function form could never be tested. In addition, Bauer in his 1990 study describes the parametric approach as being weak since restrictions need to be imposed on technology and the distribution of inefficiency terms (Chavas and Aliber, 1993).

In contrast, Färe, Grosskopf, and Lovell (1985) proposed the use of the nonparametric approach, which can be used to estimate pure technical, allocative, scale, and overall efficiencies. The nonparametric approach is independent of functional form, which is considered a major advantage (Färe, Grosskopf, and Lovell, 1985; Chavas and Aliber, 1993; Featherstone, Langemeier, and Ismet, 1997; Bravo-Ureta et al., 2007). In this approach, mathematical programming techniques are used. Disadvantages of this approach where stochastic phenomena are ignored include the potential risk of contaminating efficiency estimates with measurement error and the inability to include statistical inference in the analysis (Hallam, 1992). However, statistical information can be obtained through using the bootstrapping method. Bravo-Ureta et al. (2007) believe that the major disadvantage of this approach is that it is deterministic; it is affected by extreme observations. Other concerns include the potential sensitivity of the efficiency scores to the number of observations, the number of outputs and inputs, and the dimensionality of the frontier (Thiam, Bravo-Ureta and Rivas, 2001; Ramanathan, 2003).

Methodology

In this analysis, discretionary inputs are distinguished from nondiscretionary (i.e., quasi fixed) inputs, in which the latter inputs are out of the producer's control in the short run. Pure technical efficiency will be estimated using a nonparametric approach. According to Färe and Lovell (1978), technical efficiency is defined as the "degree to which the actual output of production unit approaches its maximum." Chavas and Aliber (1993) describe the concept of technical efficiency as determining whether or not a firm is using the best available technology in its production process. Gains in technical efficiency are achieved through improvements in managerial activities (e.g., decision making), which are directly correlated to managers' knowledge, experience and education (Bravo-Ureta et al., 2007). This is achieved by measuring how far away the farm is from the production function under variable returns to scale (Featherstone, Langemeier, and Ismet, 1997). By solving the following linear programming problem based on an input orientation, the technical efficiency (TE or λ_i) can be determined:

$$\begin{aligned} &\text{Min } \lambda_i && (1)\\ &\text{subject to:} \quad \mathbf{X'}\,\mathbf{z}_i \le \lambda_i x_i \\ &\qquad\qquad\quad \mathbf{Y'}\,\mathbf{z}_i - y_i \ge 0 \\ &\qquad\qquad\quad \mathbf{S'}\,\mathbf{z}_i \le s_\mathrm{i} \\ &\qquad\qquad\quad \mathbf{I}1' z_i = 1 \\ &\qquad\qquad\quad z_i \in \Re_+^n \end{aligned}$$

where the number of fields is denoted by N, i represents the field of interest, M is the number of inputs, S represents the quasi fixed inputs, K denotes the number of outputs, y_j represents output levels, x_i is the input level, z_i represents intensity weights. The dimensions of the vectors and matrices used in this linear programming problem are as follows: x_i is a ($M \times 1$) vector of inputs for the i^{th} field, s_i is a ($S \times 1$) vector of quasi fixed inputs for the i^{th} field, y_i is a ($K \times 1$) vector of outputs for the i^{th} field, z_i is a ($N \times 1$) vector of weights, λ_i is a scalar and satisfies the condition of $0 < \lambda_i \leq 1$, $X = [x_1, ..., x_n]$ is a ($M \times N$) matrix of observed inputs, $S=[s_1, \ldots, s_n]$ is a ($S \times N$) matrix of observed quasi fixed inputs, $Y = [y_1, \ldots, y_n]$ is a ($K \times N$) matrix of observed outputs.

In Equation 1, the intensity vector (z_i) is restricted to sum to one, which allows the technology function to consist of variable returns to scale instead of constant returns to scale. If λ_i is equal to one, then the field is defined as being technically efficient. However, λ_i is less than one, the field is technically inefficient (Featherstone, Langemeier, and Ismet, 1997).

In order to examine the effect of field and household characteristics on field efficiency scores, a tobit model was used. The following is the tobit model estimated in this paper:

$$E_i = \sum_{i=1}^{n} \beta_i x_i + e_i \quad \text{if} \quad \sum_{i=1}^{n} \beta_i x_i + e_i > 0,$$

$$E_i = 0 \,, \quad \text{otherwise}$$

where E_i is the measure of technical efficiency for each field, β_i is the estimated parameter, x_i is an explanatory variable for field i and e_i is the normally distributed error term. The software packages used to solve the linear programming models and estimate the tobit model are General Algebraic Modeling Systems (GAMS) and STATA, respectively.

Data

Data used in this study were obtained from the survey "Visite 1: Structure du Menage et Production", which was conducted between December 2006 and May 2007 in two provinces within the eastern lakes region of the DR of Congo (HarvestPlus, 2007). This survey consisted of three individual surveys: a production module, an expenditure module and a 24-hour household food consumption module. A stratified random sample of 482 households was surveyed in North and South Kivu provinces. Primarily, the data were gathered from the first module along with demographic, wealth and marketing, and household agricultural production information. For the purpose of this study, only households that produced climbing and bush beans were analyzed. Out of 482 households sampled, 87 fields owned by 80 households met the research criteria and were examined. Variable inputs used in the analysis were capital, seed expenses, and labor. Labor data were collected on a disaggregate basis across all source (i.e., family and non-family), gender and age[1]. Capital was represented by the households' total value of agricultural assets in US dollars, which is the product of the unit price of the asset in US dollars and quantity of the asset owned. Similar to Featherstone, Langemeier and Ismet (1997) and Chavas and Aliber (1993), the law of one price was assumed for labor and capital. Price or cost information was available for seed expenses. Due to the assumption that land is not a readily available or transferable, it was treated as a quasi fixed input in this analysis. Production (i.e., average yield multiplied by field size) represented the total output for each field plot. This output variable plus the above input variables per household field were used in the nonparametric estimation.

Summary statistics for the input and output variables are presented in Table 1. The average farm size is 0.149 hectares with a minimum of 0.002 hectares and a maximum of almost one hectare. The majority of the farms (70%) had less than 0.15 hectares of land. The average total value of capital owned per household was $13.36 in 2007 U.S. dollars. In terms of production, the average field produces 0.055 tonnes of beans with the maximum production level of 0.670 tonnes. The average seed price was $0.84 per kg in US dollars and the average

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[1] For this analysis, labor data is aggregated to the total number of days supplied and then divided by seven. This was done to create a value for the labor variable that was similar in magnitude to other variables.

Table 1: Summary Statistics of Production, Field and Household Characteristics

	Units	Mean (Mode)[b]	Standard Deviation	Minimum	Maximum
OUTPUT					
*Production (Avg. Yield*Land)*	*tonnes*	0.055	0.087	0.000	0.670
INPUTS					
Land	*ha*	0.149	0.183	0.002	0.982
Seed	*kg*	0.013	0.017	0.001	0.109
Capital	*2007$US*	13.360	16.410	1.000	112.500
Labor	*work week*	17.476	16.566	0.286	127.857
FARM CHARACTERISTICS[a,b]					
Physical Characteristics					
Field Size	*ha*	0.142	0.170	0.002	0.982
Soil Fertility Dummy	*0 = poor-moderate,* *1 = fertile-very fertile*	1.000		0.000	1.000
Soil Color Dummy	*0 = red,* *1 = red/brown,* *2= black*	2.000		0.000	2.000
Province Dummy	*0 = South Kivu,* *1= North Kivu*				
Distance From Household to Field	*minutes*	30.578	30.737	0.000	120.000
Demographics					
Number of Males in the Household	*people*	3.554	1.579	1.000	10.000
Percentage of Males	*%*	55.067	16.572	20.000	100.000
Dependency Ratio	*n/a*	0.946	0.874	0.000	3.000
Agricultural-Dependent Ratio	*n/a*	0.708	0.895	0.000	4.000
Age of Primary Decision Maker	*years*	46.457	12.493	18.000	74.000
Education Level of Primary Decision Maker	*years*	5.642	3.363	0.000	15.000
People Participating in Agricultural Activities	*people*	4.590	2.425	1.000	11.000
Managerial Characteristics					
Fertilizer Dummy	*0 = No Manure,* *1 = Manure*	0.000		0.000	1.000
Bean Variety Dummy	*0 = Bush Bean,* *1 = Climbing Bean*	1.000		0.000	1.000
Source of Seed Dummy	*0 = Buy, 1 = Retained*	1.000		0.000	1.000
Organizational Involvement Dummy	*0 = No Involvement,* *1= Involvement*	0.000		0.000	1.000
Risk Management Characteristics					
Number of Crops Grown per Household	*count*	3.253	1.378	1.000	7.000
Number of Fields per Household	*count*	4.614	2.546	1.000	12.000
Number of Bean Varieties Grown per Household	*count*	0.976	0.441	0.000	3.000

N = 87

[a] *N=83 for the Second Stage Analysis. Four fields were eliminated due to data restrictions.*

[b] *The median and standard deviations are not reported for the dummy variables, instead, the mode is reported.*

quantity used was 0.013 kg. The average number of weeks of labor was approximately 17.5 weeks.

The following explanatory variables are included in the tobit model: age of the primary decision maker for the field, the education level for the primary decision maker, size of the field, soil fertility dummy (i.e., poor-moderate or fertile-very fertile), soil color dummy (i.e., red, red/brown or black), fertilizer dummy (i.e., use of manure as fertilizer or no fertilizer), bean variety dummy (i.e., bush or climbing bean), province dummy (i.e., North Kivu or South Kivu), seed source dummy (i.e., retained or purchased), total number of males present in the household, the number of family members active in agricultural practices, the percentage of males within the household, distance from the household to the field, number of fields per household, number of crops grown per household, number of bean varieties grown per household, organizational involvement dummy (e.g., co-operatives, self help groups and non-government organizations), the dependency ratio[2], and the agricultural dependent ratio[3]. The last two variables were included in the analysis in attempt to capture the importance of family labor of all ages. Even though, some household members are considered to be dependents, they still participate in agricultural production.

The summary statistics provide an overview of the fields and households involved in this sample. The average field in this sample has fertile to very fertile, black colored soils, is located in the North Kivu province and is 30.57 minutes from the household. The average primary decision marker for the household has 5.61 years of schooling and is 46.5 years old. On average, no fertilizer is used on the field and there is no involvement with external organizations. Over

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[2] Dependency ratio is determined by the number of young and old dependents divided by the number of non-dependents.

[3] Agricultural dependent ratio is determined by the number of people not active in agricultural activities divided by the number of people active in agricultural activities.

half of the households in the sample grow climbing beans and use retained bean seed. The average household has 4.61 fields, grows 3.25 crops and specializes in growing one bean variety. On average, the dependency ratio is 0.93, the agricultural dependent ratio is 0.71, the number of people participating in agricultural activities is 4.59, the number of males within the household is 3.55 and the percentage of males in the household is 55%.

A correlation analysis was performed to address the possible multicollinearity issues between soil fertility and soil color and bean variety and province. In each pair-wise comparison, the correlation coefficient is less than 0.70, which suggests that multicollinearity is not a large issue in this analysis. The hypothesized relationship with efficiency scores and field and household characteristics are given in Table 2.

Results

In the analysis, the technical efficiency measure was calculated and the mean technical efficiency score for each province and for each bean variety was calculated to determine if these means are statistically significant from each other. Table 3 presents the province's and bean variety's average technical efficiency scores. The differences between these province's mean technical efficiency scores are statistically significant at the 1% level, which supports our hypothesis that, on average, North Kivu bean producers have higher technical efficiency scores than South Kivu bean producers. Similar, the differences in the mean technical efficiency scores for the climbing and bush beans were statistically significant at the 1% level. This result supports our hypothesis that, on average, climbing beans have higher technical efficiency scores than bush beans.

Table 2: Anticipated Signs of Stage Two Variables

Variable	Measure	Ho Sign	Rationale
Physical Characteristics			
Field Size	*ha*	?	A field may exhibit size economies or diseconomies, which could have a positive or negative influence on efficiency, respectively. Larger fields may result in more production and thus may be more efficient. However, larger fields may also be source of resource misallocation if the field cannot be properly maintained or if its soil quantity (e.g., color, fertility) is not adequate.
Soil Fertility	*0 = poor-moderate, 1 = fertile-very fertile*	+	Higher soil fertility level is viewed as more favorable for agricultural activities.
Soil Color	*0 = red, 1 = red/brown, 2= black*	+	Soils darker in color tend to be more fertile. Therefore, rich-colored soil is associated with higher yield rates.
Province Dummy	*0 = South Kivu, 1= North Kivu*	+	Geographic characteristics of North Kivu are viewed as being more favorable for agricultural activities than South Kivu.
Distance From Household to Field	*minutes*	-	Distance traveled between household and field is viewed as a transaction cost. Thus the greater the travel time, the less efficient the producer.
Demographics			
Number of Males in the Household	*people*	+	Males were once perceived to be more efficient workers than females; however recent research is contesting this belief. Although, males may not be considered more efficient workers than females, they do have better access to organizational goods and capital resources. These opportunities may help males become more efficient than females (Adesina and Djato, 1997).
Percentage of Males	*%*	+	More males within the family labor force may improve the overall efficiency. Also see rationale for the number of males in the household.
Dependency Ratio	*n/a*	-	Dependency Ratio is determined by the number of dependents divided by the number of non-dependents. A larger ratio number indicates less family members being able to participate in agricultural activities, which would lower efficiency.
Agricultural-Dependent Ratio	*n/a*	-	Agricultural Dependent Ratio is determined by the number of people not active in agricultural activities divided by the number of people active. Thus, a large ratio is associated with a negative impact on efficiency.

Table 2 (cont'd)

Variable	Measure	Ho Sign	Rationale
Demographics (cont'd)			
Age of Primary Decision Maker	*years*	+	Years of experience and knowledge represented by the decision maker's age are expected to have a positive impact on efficient rates.
Education Level of Primary Decision Maker	*years*	+	The level of education is assumed to be positively associated with efficiency
People Participating in Agricultural Activities	*people*	+	Given that the majority of the agricultural activities are labor intensive, a large number of people participating in these activities leads to a higher efficiency.
Managerial Characteristics			
Fertilizer Dummy	*0 = No Manure, 1 = Manure*	+	The use of manure as fertilizer is rarely implemented but fertilizer is known to help increase yields.
Bean Variety Dummy	*0 = Bush Bean, 1 = Climbing Bean*	+	Studies have found that climbing bean varieties are associated with higher yields.
Source of Seed	*0 = Buy, 1 = Retained*	-	Using retained seed may negatively affect efficiency if the parent bean plant has been adversely cross pollinated.
Organizational Involvement	*0 = No Involvement, 1= Involvement*	+	By being involved in organizations (e.g., co-operatives, NGO's), producers are introduced to advancements in technology and agricultural methods as well as provide access to new seed varieties. Therefore, producer's involvement is believed to enhance a producer's efficiency.
Risk Management Characteristics			
Number of Crops Grown per Household	*count*	?	Variety among crops may help to diversify away risk but it may result in misallocation of time and labor effort.
Number of Fields per Household	*count*	?	More fields may be associated with a greater yield and thus have a positive impact on efficiency. However, it could represent a misallocation of time and labor effort. It brings into question the issue of extensive versus intensive farming.
Number of Bean Varieties Grown per Household	*count*	?	Variety among bean crops may help to diversify away risk but it may result in misallocation of time and labor effort.

Table 3: Mean Technical Efficiency Scores between Provinces and between Bean Varieties

	MeanTechnical Efficiency
North Kivu	0.735
South Kivu	0.548
Bush Bean	0.538
Climbing Bean	0.791

From all observations, the average score for mean technical efficiency is 65.8%, which is below the average score for mean technical efficiency (78.3%) discovered by Bravo-Ureta et al. in their 2007 meta-regression analysis. The average, mean technical efficiency scores for lower income countries[4] and for African countries were 74.1% and 73.7%, respectively (Bravo-Ureta et al., 2007). When analyzing by product, the average mean technical efficiency score for the other grains category is 73.2%, with a minimum score of 33.0% and maximum score of 99.4% (Bravo-Ureta et al., 2007). In the present study, the mean technical efficiency score for all observations is below these previously estimated efficiency values. However, the average score for mean technical efficiency associated with climbing bean is 79.1%, which is above the other grain category efficiency value determined in the 2007 study by Bravo-Ureta et al..

Thiam, Bravo-Ureta and Rivas (2001) used a meta-analysis to examine technical efficiencies in developing countries' agriculture and found that the average farm level

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[4] The classification of lower income countries is based on the World Bank (2005) classification. DR of Congo is considered to be a lower income country; however, it was not one of the countries included in the Bravo-Ureta et al. (2007) study.

technical efficiency score was 68%. This value is between the average technical efficiency scores for North and South Kivu (73.5% and 54.8%, respectively).

In the analysis (Figure 1), twenty-five (28.7%) of the total fields are technically efficient. Approximately half of the fields have a technically efficient score of 70% or higher. Measures for technical efficiency range from 11.9% to 100%, with a mean of 65.8%. If each field was purely technically efficient, then the output for the field could increase by 34.2%, given the same level of inputs and technology.

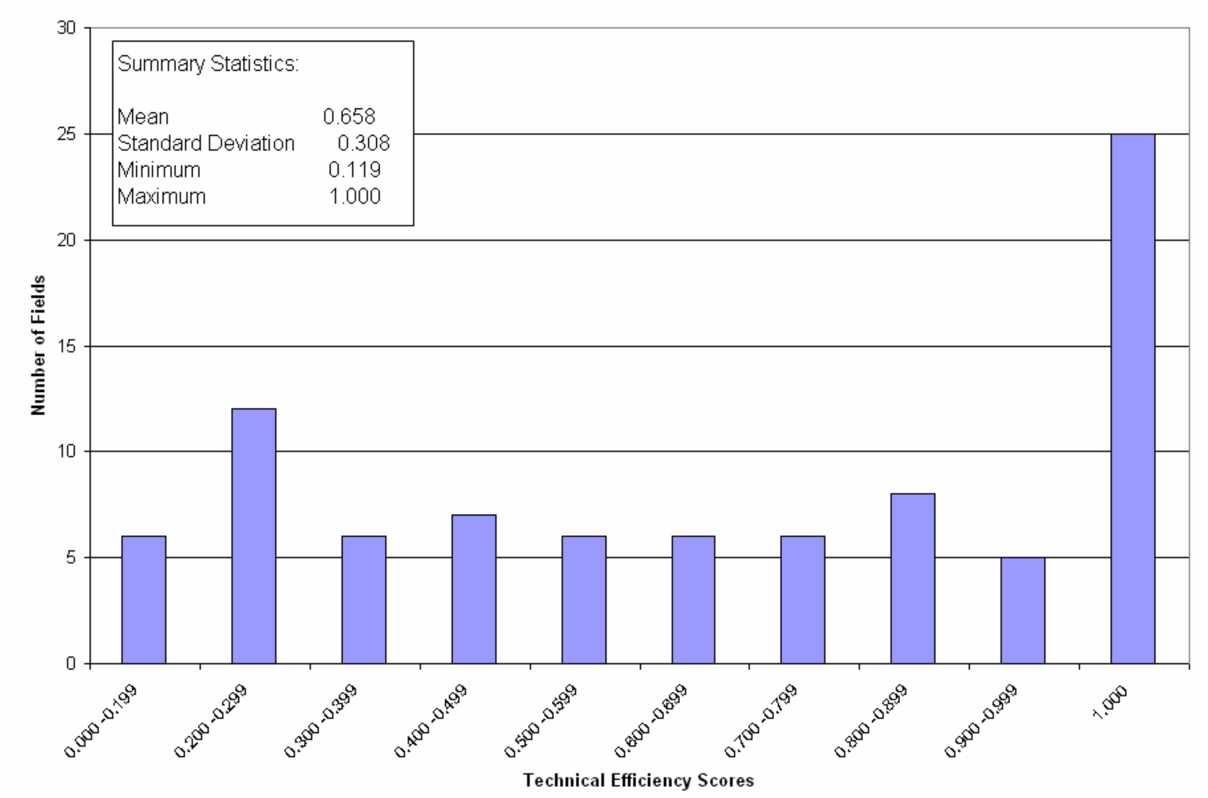

Figure 1: Summary Statistics and Distributions of Technical Efficiency Measures for All Fields

A tobit model was used to identify the correlation of efficiency to other characteristics associated with each field. Results from the tobit analysis are found in Table 4. Significant field and household characteristic variables associated with technical efficiency are field size, bean variety grown, and age of the primary decision maker. As expected, climbing beans (i.e., bean variety =1) are correlated positively with technical efficiency. According to the elasticity values, age has the largest impact on the predicted technical efficiency score.

Table 4: Relationship Among Technical Efficiency and Field and Household Characteristics

	Technical Efficiency			Technical Efficiency	
Independent Variables	Coefficient (Std Error)	Elasticity	Independent Variables	Coefficient (Std Error)	Elasticity
Field Size	-0.467 **	-0.094	*Percentage of Males*	0.342	0.268
	(0.214)			(0.525)	
Soil Fertility (Fertile)	0.035	0.030	*Dependency Ratio*	-0.026	-0.034
	(0.090)			(0.055)	
Soil Color (Red/Brown)	-0.024	-0.006	*Agricultural-Dependent Ratio*	-0.049	-0.046
	(0.116)			(0.108)	
Soil Color (Black)	0.064	0.042	*Fertilizer Use (Manure)*	-0.087	-0.026
	(0.100)			(0.110)	
Province (North Kivu)	-0.017	-0.014	*Bean Variety (Climbing Bean)*	0.219 *	0.160
	(0.170)			(0.113)	
Distance From Household to Field	-0.002	-0.084	*Source of Seed (Retained)*	-0.124	-0.106
	(0.002)			(0.085)	
Age of Primary Decision Maker	-0.007 *	-0.484	*Organizational Involvement (Involved)*	0.122	0.007
	(0.004)			(0.197)	
Education Level of Primary Decision Maker	-0.013	-0.103	*Number of Crops Grown per Household*	-0.052	-0.234
	(0.011)			(0.048)	
People Participating in Agricultural Activities	-0.028	-0.182	*Number of Fields per Household*	0.004	0.026
	(0.055)			(0.030)	
Number of Males in the House	-0.004	-0.021	*Number of Bean Varieties Grown per Household*	0.006	0.008
	(0.075)			(0.095)	
Likelihood Ratio Test	62.970 ***		*Intercept*	1.349	
McFadden's R^2	0.4559			(0.400)	

Note: *,**, *** denote significance at the 10%, 5% and 1% level, respectively

Discussion

Age has a negative impact on technical efficiency, which does not coincide with our hypothesis. We originally believed that age would capture the wealth of knowledge gained through years of experience and thus, have a positive impact on technical efficiency. This negative relationship suggests that as a person becomes older they may be more hesitant and less likely to adopt new technology that may improve their technical efficiency. However, it is plausible that the relationship between the age of the primary decision maker and technical efficiency is a non-linear.

Field size has a negative influence on technical efficiency. Given that technical efficiency measures a manager's ability and skills in managing the field, the results indicate that increases in field size negatively affects producers' ability to effectively and efficiency manage the field. This relationship may indicate that fields exhibit size diseconomies. By increasing the field size, which could be considered an extensive farming strategy, there may be a misallocation of time, labor and other resources. Excessive time, energy, and resources may be spent on obtaining, preparing and maintaining the new land which may result in the overall cost of increasing the field size outweighing the additional land's benefits. It is important to note that land limitations are a pertinent issue in these provinces. Therefore, even if the producer had adequate resources to properly manage an increase in field size, the probability of being able to obtain more land is low. The producer may be more efficient if they concentrate on making managerial decisions (e.g., crop decisions and fertilizer use decisions) that improve the efficiency of their field at its current size (i.e., focus on intensive farming).

The positive significant relationship between climbing beans and technical efficiency provides a motivation for bean producers to grow climbing beans instead of bush beans. This finding is relevant to policy makers as it can help ameliorate food security and health problems facing the DR Congo and other developing countries. Given the current turmoil facing the DR Congo, in particular North and South Kivu, relief in the form of supplying climbing bean seeds may be needed to boost agricultural production in these areas. Growing climbing beans may increase efficiency, which in turn may lead to more food secure households. Additionally, climbing beans may increase the nutritional value of the produced bean crop. Many research projects have been conducted that focus on improving the micronutrient content of the climbing bean, primarily the zinc and iron content. For example, HarvestPlus, an organization that develops crops for better nutrition, has implemented research programs in African countries to improve the iron and zinc content in agronomically superior bean varieties such as climbing bean varieties (HarvestPlus, 2006). These nutritional enhancements will help alleviate current health problems facing many African countries, particularly anemia.

Possible limitations of this study and its findings are attributed mainly to the data set. Limited data were available on essential production factors, primarily field size and crop production, which hinders our ability to gain an accurate insight into household-level agricultural production capacity (Dalton, 2008). The limited data on the names of the bean varieties grown made it difficult to determine whether biofortified seeds are being grown and consumed by the household. The lack of labor information limits our ability to determine the relationship between family labor, non-family labor and efficiency scores. Also, the absence of land price in the data creates some challenges.

Due to the limited data on factors of production (e.g., price of land and labor), extension into allocative and scale efficiency measures was prohibited. It may be possible to conduct further efficiency analysis (e.g., calculating allocative, scale and overall efficiency scores) by using techniques such as (1) simulating input prices using the Monte Carlo simulation technique; (2) using implicit prices derived from constraints; and (3) developing pricing indices for capital and labor. In spite of these data limitations, this research has given us some insight into the efficiency of bean producers in North and South Kivu as well as identified factors that influence these efficiency scores.

Conclusion

Beans are an essential food crop for many people around the world. A great deal of research and development efforts have focused on improving the nutrition content (e.g., increasing the iron content) and improving the yield. This study used a nonparametric approach to estimate technical efficiencies of a sample of bean producers in DR Congo. Data were gathered from 87 fields in North and South Kivu provinces during 2006 and 2007.

On average, farms are 66% technically efficient. North Kivu bean producers and climbing bean producers have, on average, a higher technical efficiency score than their counterparts. Results from the tobit analysis suggests that increases in field size and age of the primary decision maker will decrease technical efficiency scores. Climbing beans have a positive and significant relationship with technical efficiency. In addition to improving efficiency, climbing beans may lead to improvements in mitigating the anemia health problem in the DR Congo. In the tobit analysis, field location is not found to have a significant relationship with technical efficiency. Thus, our hypothesis about the significance of bean variety is reinforced by the tobit analysis results while our hypothesis concerning the significance of field location is not.

Little information could be gathered from the tobit results in regards to the importance of family and non-family labor or the impact of crop diversification on efficiency. A more in depth analysis of the effect of family labor and certain managerial decisions (e.g., the number of crops grown per household) on efficiency scores is warranted. Moreover, further insight into the efficiency of bean producers in DR Congo can be gained from a more rigorous analysis involving all four efficiency measures: technical, allocative, scale and overall efficiency measures.

Therefore, future research is needed to identify the exact factors that influence these efficiency measures for bean producers in DR Congo. Accurate efficiency measures and identification of factors that affect these measures are critical to the development of policy decisions involving farm management and training programs.

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