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# ANALYSIS OF TECHNICAL AGRICULTURAL EFFICIENCY IN BURUNDI: CASE STUDY OF STAPLE CROP

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**Abstract**

The study aims at analyzing of Burundi agricultural technical efficiency determinants of staple crop during the mayor crop season B in 2011-2012. The results have shown a low level of agricultural efficiency using the stochastic frontier analysis method. An average of technical efficiency level of 0.48. The agricultural efficiency level observed in Burundi agricultural sector showed a possibility of doubling the agricultural production using the same inputs by achieving the optimum efficiency. The determinants of agricultural efficiency enhancement included improving access to market, road, extension, agricultural loan and reduction of vulnerability of young and female farmers. A focus on agricultural efficiency enhancement might be prioritized to increase agricultural income.

**Key words:** Agricultural production, stochastic frontier, rural development

## 1. Introduction

It is estimated that in the world 80% of the vulnerable people and the poor are living in rural areas (FAO, 2016) and the existence of the correlation between the vulnerability and poverty is also stated (Damas - Md.israt, 2004). The climate change and the complete dependence on agricultural income in a country with low productivity in the agriculture sector and no market-oriented agriculture make agricultural people more vulnerable to climate change, poverty and limit the overall development of the country (World Bank, 2002).

Burundi is among the poor countries and agriculture is the leading source of income, especially in rural areas where 88.2% of the population is living. Agriculture accounts for 89% of the total workforce. The gross domestic product per capita is among the lowest in the world. It was 286 USD in 2014 and its annual growth was estimated to be at a rate of 1.3% in 2014. The agricultural gross value added contributed at a rate of 43% to national gross domestic product in 2015 (World Bank Indicators, 2016)

Rural income generation enhancement in Burundi could be among the pillars of the transformation of rural life and improve the well-being of the rural population. Due to the fact that rural population is the majority of the population and the agricultural sector is the core income generation source sector, it is fundamental to exploit it efficiently and boost agricultural productivity and consequently permit the movement of labor and surplus to other sectors.

Even if the growth of gross domestic product per capita could be achieved, the positive effect of the economic growth in rural areas could be explained by the growth of rural income. The expansion of rural income could be achieved by increasing the productivity of rural economic activities. Consequently, as the main economic activity in rural areas in Burundi is agriculture, agricultural productivity enhancement is among the drivers of rural income rising and poverty reduction management.

In Burundi, the population is growing and the agricultural holding area per household is decreasing each year. The arable land per capita is decreasing, it passed from 0.22ha per capita in 1981 to 0.11ha per capita in 2014 (FAOSTAT database, 2016). Considering this decrease in the arable land per capita and increasing population, it can be assumed that the increasing agricultural productivityas the mayor economic sector could be one of the solutions to the problem.
It has been proven that a positive correlation exists between agricultural productivity improvement and poverty reduction (Mellor, 1999; Datt - Ravallion, 1998; Timmer, 1997; Byerlee*et al.*, 2009; Schneider - Gugerty, 2011; Rebati*et al.*, 2013). Schneider and Gugerty (2011) explained the existence of multiple pathways through which improvement of agricultural productivity can reduce poverty, and these include real income changes, employment generation, rural non-farm multiplier effects and food prices effects.

Besides, low productivity in agriculture increases the pressure on natural resources, the vulnerability of the agricultural sector and poverty in rural areas. The analysis of factors that could be emphasized to enhance the efficiency and productivity of agricultural sector is fundamental in order to enhance the quality of life in rural areas.

Moreover, It is also relevant to analyze the factors that could enhance productivity in the principal economic sector in rural areas when we need to improve the standard of life of rural inhabitants and this requires the analysis of the factors that affects agricultural productivity, and which could be the focus in increasing agriculture efficiency.

The findings of this research could clarify the possibility of running the pro-poor policy and the factors to focus on in the management and promotion of rural development.

The analysis of agricultural efficiency enables us to analyze the factors that negatively or positively affect rural households to enhance their agriculture efficiency. In addition, it could be focused on to increase efficiency in agriculture.

**Objective and scope of the research**

Burundi is highly populated, with an estimation of population of 10.82 million in 2014 with 88.2% living in rural areas; its projection in 2030 is 13.4 million (World Bank Indicators, 2016). Although, 88.2% of the total population is in agriculture, the main sources of income in rural areas is agriculture, but its productivity does not allow rural people to get enough food and have high living standards. Based on that, it may be more indispensable to increase agricultural productivity. Considering the limit access on inputs, enhancement of agricultural production could be achieved through the realization enhancement of agricultural technical efficiency. That is why the analysis of agricultural technical efficiency could permit the exploration of the factors drive the increasing of technical efficiency and on which policy makers could focus on to improve agricultural productivity and standards of rural life.

Considering the fact that agricultural sector is dominant in Burundi, the factors that permit the increasing of agricultural productivity are very interesting in the promotion of economic growth and rural development. The study aims to explore the elements that permit the enhancement of agricultural efficiency. The elements causing technical inefficiency in the agricultural household are analyzed. The main objective of the study is to analyze the determinants of technical agricultural efficiency in Burundi.The study specifically aims to respond to the following research questions. The usage of secondary data of agricultural surveys (2011-2012) enables us to analyze:

Which efficiency level was observed in the agricultural sector in Burundi?
What determines agricultural efficiency in Burundi?
What factors have positive or negative impacts on the efficiency of Burundi's agriculture?

## 2. Literature review

### 2.1 Concepts of Production Efficiency

Efficiency farming is a kind of farming that requests fewer inputs than other to produce the agriculture output (Townsend *et al.*, 1998). Production efficiency analysis is based on production function, which is defined by the relation between the level of inputs and its related output (Schmidt, 1986) and is focused on the maximization of output under inputs constraint or minimization of inputs for a certain level of output (Besanko - Braeutigam, 2005). The frontier analysis is based on the technological relationships between inputs and outputs specified in the production function as mentioned above:

$$f(x_i) = max\{y_i: T(x_i, y_i)\} \quad (1)$$

Where$y_i$ indicates the maximum level of output (frontier output) the household or firm can produce,$x_i$ represents the different inputs used and $T(x_i, y_i)$ represents the technological relationships between inputs and outputs. Considering the existing level of input, three different situations are assumed in the comparison of the production possibility curve or frontier production curve: 1) efficient and attainable production situated on the frontier output level; 2) attainable but inefficient production for production level below frontier level; 3) unattainable production for the points above the frontier level.

Generally, there are several ways by which the increasing of output level can be achieved.

Through *horizontal approach* which consists of an increase in inputs used in production. However, input increasing is realizable if either the price of inputs is decreasing or when increasing output price
Through *improvement approach* which is connected to the role of improvement of socio-economic, institutional and environmental constraints to the enhancement of production taking unchangeable the existing level of inputs.
Through *technological enhancement of production* which includes improved production techniques, using modern and improved seed, modern fertilizer and chemicals and it is usually termed as a transformation approach (Alene, 2003).

In an analysis of efficiency, we need to catch the difference between productivity, which indicates the ratio of output (s) to inputs, while efficiency indicates the highest productivity level from each input level (Coelli*et al.*, 1998). It is distinguished technical efficiency, which is related to physical inputs minimization or physical outputs maximization productivity; allocative efficiency, which is related to the right use of mixing input regarding the relative price of each price (input allocative efficiency) or the production of the right mix of output given their relative prices (output allocative efficiency) (Kumbhaker - Lovell, 2000). The economic (overall) efficiency is achieved for a firm which realizes the technical and allocative efficiency.

The graphical illustration of these two concepts is by using a simple example of two inputs (x1, x2) – two outputs (y1, y2), production. The efficiency is considered if the optimal combination of inputs is used for a given level of output (an input-orientation) or the optimal output production given a set of inputs (output-orientation).
In Figure 3A, the mix of input use allows the firm to produce a given level of output ($y_1^*$, $y_2^*$). The production of same level output could have been realized by the use of mixing fewer inputs represented by

the point ‘b’, which is on the isoquant actually representing the minimum level of inputs required for ($y_1^*$, $y_2^*$) production, in figure Iso($y_1^*$, $y_2^*$).

0B/0A determined the input-oriented level of technical efficiency designed ($Te_i(y,x)$), whereas the production ($y_1^*$, $y_2^*$) with the least cost combination of input is given by the point ‘C’ (the point, where the marginal rate of technical substitution between the factors of production is equal to their relative price ratio $w_2/w_1$). In order to attain the usage of the same level of cost of input in production, we need to reduce the inputs to point ‘D’.

The cost efficiency (CE(y,x,w)) is determined by the ratio 0D/0A, and then CE(y,x,w)/$TE_i$(y,x), or 0D/0B. Figure 3A indicates the input allocative efficiency ($AE_i$(y,w,w)) (Kumbhaker - Lovell, 2000)
The output orientation of the maximization of production is figured by the production possibility frontier for a given set of inputs (see Figure 3B). The production obtained at the point could be augmented to point b if an efficient use of input is realized. Therefore, the output oriented maximization given by the attainment of technical efficiency ($TE_o$(y,x)) is given by the ratio of 0A/0B. This situation is the equivalent of the input oriented measure of technical efficiency in the situation of constant returns to scale whereas point ‘B’ indicates technical efficiency due to the fact that it lies on the production possibility frontier and the higher revenue is realized at point ‘C’ where the marginal rate of transformation between the input is equal to the inverse of the price ratio p2/p1. In order to get the same level of

revenue as the.one at point 'C' while the combination of output and input is unchanged, the output of the firm need to be augmented to point 'D'. Consequently, the efficiency revenue (RE(y,x,p)) is given by the ratio 0A/0D determining the efficiency revenue (RE(y,x,p)) and RE(y,x,w)/$te_i$(y,x), or 0B/0D in figure 3B gives the output allocative efficiency ($AE_o$(y,w,w)).( Kumbhaker and Lovell, 2000)

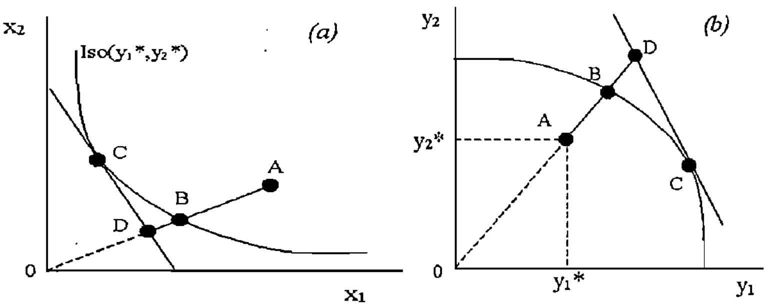



**Figure 1A and 1BInput (a) and output (b) oriented efficiency measures**

Source: Herrero- Pascoe, 2002

## 2.2 Measurement of technical efficiency

Frontier models imply the determination of technical efficiency by the comparison of the performance of an individual firm to the most efficient firm in the industry. Different approaches are used in the efficiency measurement of firms. The most widely used are stochastic frontier analysis (SFA) that is a parametric approach using econometric methods and the other one is a non-parametric approach named data envelopment analysis (DEA) using mathematical programming and assuming that all deviations from the frontier output (for example, inefficiencies due to bad weather strike, shortage of inputs) are due to the firm technical inefficiency while for stochastic frontier analysis, both an efficiency component and a random error are considered.

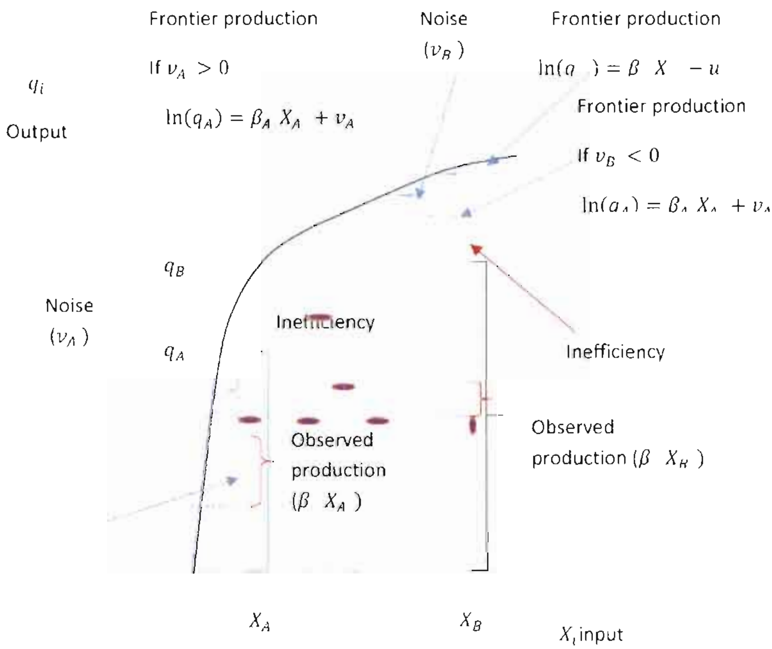
It is more often preferable to use SFA in estimation efficiencies of production systems for two reasons: 1) the very nature of agricultural production depends on climatic conditions and is affected by measurement errors that attribute for statistical noise in data sets; 2) the possibilities allowed by stochastic frontier model to decompose the errors terms in statistical noises and inefficiencies measure that allows statistical tests on the validity of the model specification (Gelaw, 2004 , Chen , 2007).

Battese and Coelli (1993, p.1.) argued:" the *stochastic frontier production function postulates the existence of technical inefficiencies of production of firms involved in producing a particular output. For* *a given combination of inputs levels, it is assumed that the realized production of a firm is bounded above by the sum of a parametric function of known inputs, involving unknown parameters, and a random error, associated with measurement of the level of production or other factors, such as the effects of weather, strikes, damaged product, etc. The greater the amount by which the realized production falls short of this stochastic frontier production, the greater the level of technical inefficiency*".

Considering the stochastic frontier production expressed in a Cobb-Douglas production form like: $\ln(q_i) = \beta_i lnX_i + v_i - u_i$, where $\ln(q_i)$ indicates the logarithm of the farm household's output i$^{th}$, $\beta_i$represents the vector of unknown coefficients associated to $X_i$ which is indicating the vector of inputs used in the production of i$^{th}$ output , $v_i$ is the expression of random error designing the statistical noise and $u_i$ is a non-negative error term which indicates the inefficiency effects. The figure above illustrates the stochastic frontier production function.

In the following Figure 2, we assume that two farm households a and b use $X_a$ and $X_b$ inputs, respectively, to get their outputs $q_a$ and $X_b$shown by the illustration. The observed values represent the frontier values which is the situation of lack of inefficiency in production (in case where$u_A = 0 and u_B = 0$) and then the frontier level of output is determined by the function $\ln(q_A) = \beta_A lnX_A + v_A$ and function $\ln(q_B) = \beta_B lnX_B + v_B$ for these two farms a and b. In the illustration it is also clear that the frontier output for the household a is above the deterministic level of output due to the positive noise effects ($v_A > 0$) , and for the producer b , its frontier output lies below the deterministic level of output caused by the negative noise effects ($v_B < 0$) ( Coelli*et al.*, 2005).

**Figure 1. Stochastic frontier production analysis illustration**




Source: Neuman *et al.*, 2010

The efficiency analysis is applicable to a broad range of studies, as Bahta and Baker (2015) used efficiency analysis in order to search the competitiveness and the factors affecting it of rural livestock sector in Botswana and in examining a cross section of farm level data of a sample of 556 randomly selected livestock producers to investigate the profit efficiency and the competitiveness of three farm size categories of smallholder livestock farmers. Their results let them conclude that there was high possibility to improve beef profitability, scale effects on profit efficiency are generally positive but the results indicate a number of interactions between scale and other variables such as off-farm income and the use of credit.

Bravo-Ureta and Pinheiro (2012) made a review and critiques of the frontier literature in farm efficiency analysis in developing countries and a total of 30 studies from 14 different countries were examined. They have realized that the average technical efficiency the index from all studies reviewed was 0.72 and the few studies that focused on allocative and economic efficiency showed the average of 68% and 43%, respectively. These results helped them to conclude the existence of the considerable possibility to increase agricultural output without additional inputs given the existing technology It has also been noticed that most studies reviewed tried to explain farm level variation technical efficiency using mostly as variables farm education and experience, contacts with extension and access to credit and farm size. Except the farm size, all results showed that these variables tended to have a positive and statistically significant impact on technical efficiency.

Muange*et al.* (2015) analyzed the effects of social networks on technical efficiency in smallholder agriculture in cereal producers in Tanzania and the results of efficiency analysis with stochastic frontier analysis in maize and sorghum. The investigation of social network influence on technical efficiency of smallholder of cereals producers showed that the effects of social networks on efficiency differ by crop, and inter-village networks positively influence the technical efficiency of improved sorghum varieties, but have no effect in case of maize and the existence links to public extension services to increase the efficiency of improved maize.

## 3. Material and research methods

### 3.1. Theoretical framework of the study

### Production efficiency analysis methods

The fundamental objective of the agricultural efficiency analysis is to determine the level of efficiency in the sector and the factor of inefficiency based on the production function. The efficiency of the agricultural production is analyzed using the stochastic frontier model. The model was chosen due to its capability of decomposing the error term in statistical noises and inefficiency component that permit to determine the level of efficiency of each farm household.

The stochastic frontier production function is specified as;

$$y_i = f(x_i; \beta) e^{V_i} TE_i \ , \quad (2)$$

Where $y_i$ indicates the i[th] household's output and $x_i$ the combination of inputs utilized in i[th] household's output the production.

$f(x_i; \beta)$ represents the production frontier and $\beta$ is the vector of frontier coefficient to be estimated, $e^{Vi}$ is the indicator of random shocks and $TE_i$ is the representation of the technical efficiency of the farm household .

Coelli*et al.* (2005) defined technical efficiency of an individual farm as the ratio of observed output to the corresponding (frontier or potential if is technical efficiency is realized) output. In addition, technical inefficiency is determined by the difference in the amount between the observed output and the frontier production. Technical efficiency is the ratio varying from 0 to 1 and which is equal to one (1) for a farm household that its observed output attained the frontier output or potential output level and the technical efficiency is less than one in the case of observed output is less than frontier output level and implies the presence of technical inefficiency. Technical inefficiency could be calculated by using the formula below:

$$TE_i = \frac{y_i}{f(x_i;\beta)e^{Vi}} \text{where } 0 \leq TE_i \leq 1 \qquad (3)$$

The most used stochastic frontier functions are those based on the Cobb Douglas production function and translog production function model. These are expressed by these formulas:

Cobb Douglas: $\ln(y_i) = \beta_0 + \beta_1 \sum_{i=1}^{s} \ln(x_i) + v_i\text{-}u_i$

(4)

Where $\ln(x_i)$ are the natural logarithmic transformation,

βs indicate the parameters to be estimated and $y_i$ the output of i[th] farm household in Burundi.$x_i$ are the inputs and $v_i$ is the random error arising from the error of measurement of in inputs chosen or output, $u_i$indicated the non negative random variables that represent the technical inefficiency of individual farm household i. Half normal, exponential, truncated normal and gamma distributions are widely used in scientific studies and for each, certain assumptions have to be fulfilled with their specific characteristics.

For the half normal distribution, the marginal distribution of the global error $\varepsilon_i = v_i - u_i$is given by the below formula:

$$Ei= f(u;\varepsilon)du = \frac{2}{2\pi\sigma_u\sigma_v} \quad \exp\{-\frac{u^2}{2\sigma_u^2} - \frac{(\varepsilon+u)^2}{2\sigma_v^2}\}=\frac{2}{\sigma}\phi\left(\frac{\varepsilon}{\sigma}\right)\left[1 - \varphi\left(\frac{\varepsilon\lambda}{\sigma}\right)\right]$$

(5)

for$-\infty < E_i < \infty$

and where and $\lambda= \frac{\sigma_u}{\sigma_v}$ are variance parameters and $\phi(.)$Indicates the standard probability density function and φ ( .) represents the standard cumulative density function. Kumbhakar and Lovell (2003) stated that λ in the above equation indicates the relative contribution of $u_i$and $v_i$, respectively to ei. Therefore, if $\lambda \to 0$, either $\sigma_v^2 \to \infty$ or $\sigma_u^2 \to 0$, and in this case a situation occurs, where the symmetric error $v_i$ dominates the inefficiency part $u_i$ and, if $\lambda \to \infty$ either $\sigma_v^2 \to 0$ or $\sigma_u^2 \to \infty$ , in this case, $u_i$ dominates $v_i$ in $\varepsilon$i.

Considering the marginal distribution in the former equation of $\varepsilon$i, the further step is to form and maximize the likelihood function concerning$\beta$,$\sigma^2$ and λ. In order to estimate the unknown coefficients of the parameters and then the measure of inefficiency

$u_i$.nevertheless,the decomposition of error ei in $u_i$ and $v_i$ is not realizable. To get the solution a conditional distribution of $u_i$ might be considered that was first introduced by Jondrow *et al.* (1982) expressed as follows:

$$E(u_i/\varepsilon i) = \hat{}u_i = \frac{\sigma\lambda}{1+\lambda^2}\left[\frac{\phi(\frac{\varepsilon\lambda}{\sigma})}{1-\varphi(-\frac{\varepsilon\lambda}{\sigma})} - \left(\frac{å\lambda}{\sigma}\right)\right] \qquad (6)$$

Considering the estimates of $u_i$in the above equation, the technical efficiency of the individual household is given by the equation below expressed:

$$TE_i = \exp\left(-\hat{}u_i\right) = TE_i = \frac{y_i}{f(x_i;\beta)e^{V_i}} \text{where } 0 \leq TE_i \leq 1$$

(7)

The average of the individual household farm technical efficiency is permitted to get the technical efficiency of agriculture in Burundi.

It has been argued in many empirical studies on productivity and efficiency the important role played by socio-economic, institutional and environmental factors in efficient differential among farmers (Aigner*et al.*, 1977, Battese-Coelli, 1995, Bravo-Ureta-Pinheiro, 1997; Obwona, 2006; Nyagaka*et al.*, 2010).

These studies have guided us in the selection of the explanatory variables of inefficiency and have been selected demographic factors (household size, age, gender and education level of head of household), institutional factors (access to extension services, access to market, access to road, access to fertilizer marketplace, access to vocational or adult educational centers, access to producers' organizations), resources factors (non-farm income generated, number of livestock owned). The determination of the coefficients of these explanatory variables has been done using the inefficiency model expressed in the equation below:

$$TE_i = P_0 + \sum_{i=1}^{n} P_i Z_i + \varphi_i \qquad (8)$$

where$U_i$ determines the technical inefficiency , $P_i$ are the parameters of the model to be estimated and $Z_i$ indicates the group of explanatory variables of inefficiency and $\varphi_i$ represents the random error term ($\varphi_i \sim N(0, \sigma_i^2)$).

Generally, two methodological approaches are used in the estimation of inefficiency model based on the stochastic frontier analysis; one stage procedure by simultaneous estimation of both production function and sources of inefficiency and another in two-stage estimation technique in which firstly the stochastic production frontier and the scores of efficiency are estimated, and the second stage is the regression analysis of the derived efficiency scores and the set of explanatory variables by the method of ordinary least squares. Nevertheless, the two-stage methodological approach is criticized to the capability of influence the knowledge of inefficiency by farmers may affect the choice of inputs (Chirwa, 2007). In our study, the estimation of determinants of technical inefficiency will be done by using the one stage estimation method.

### 3.2 The empirical model and the selected variables

The technical efficiency of agriculture in Burundi is realized using one stage of the stochastic frontier analysis method. The inputs were selected based on the Cobb Douglas production function Cobb Douglas: $\ln(y_i) = \beta_0 + \beta_1 \sum_{i=1}^{s} \ln(x_i) + v_i - u_i$`

The agricultural inputs considered for the technical efficiency analysis are composed by the agricultural land measured in hectare, which is the basis of the agricultural production, the labor measured in hours of work of household,it combined paid and non-paid workforce that are spent on agricultural and so related activities (examples as carriage of agricultural inputs and production), seeds in equivalents cereals. The households with available data for stochastic frontier analysis were estimated to 1071.

The technical efficiency scores were computed using the formula $TE_i = \exp(-\hat{}u_i) = TE_i = \frac{y_i}{f(x_i;\beta)e^{Vi}}$ where $0 \leq TE_i \leq 1$

The determinants of technical efficiency were obtained using by the regression of technical efficiency level as dependent variables and a set of socio economic factors as independent variables using the above formula: $TE_i = P_0 + \sum_{i=1}^{n} P_i Z_i + \varphi_i$ (10)

where $U_i$ determines the technical inefficiency , $P_i$ are the parameters of the model to be estimated, $Z_i$ and $\varphi_i$ represents the random error term ($\varphi_i \sim N(0, \sigma_i^2)$), and $Z_i$ indicates the group of explanatory variables of inefficiency that are explained in the following table

Table 1: Explanatory variables of inefficiency

| Variables | Description |
|---|---|
| Sex of household head (dummy variable) | The sex of head of household indicated the gender of head of household and is dummy variable ( female of males |
| Reading / writing skills of the Kirundi of head of household | the reading and writing skills of national language is evaluating the ability of household to read or/ write the national language, it is linked to the ability to get written information by himself , it's a categorical variables with 3 categories , able to read, able to read and write and unable to read and write |
| Reading / writing skills of foreign language of head of household | the reading and writing skills of foreigner language is evaluating the ability of household to read or/ write the any foreign language , it is linked to the ability to get written information by himself in any other language , it's a categorical variables with 3 categories , able to read, able to read and write and unable to read and write |
| Membership of producer' organization ( head of household) | It assesses the participation of agricultural producer's organization. It is a dummy variable and takes 0 if 's organization, and 1 if it is the head of household is member of producers organizations |
| Benefiting of extension (head of household) | It assesses the access to extension services and it is dummy variable (yes =1 if the head of household is benefiting of extension services, no= 0 if the head of household is not benefiting of any extension services. |

| | |
|---|---|
| Head of household has got credit in the last 3 years (dummy variables ) | It assesses the access to credit in the last 3 years, it is a dummy variable. It takes value 0 if the household head have not got any credit it the last three years otherwise it is yes= 1 |
| A road passes through the village | It assesses the access to road in the village and it is dummy variable (yes =1 and no =0) |
| Road in good condition in the community | it assesses how is the road available is and it is facilitation of communication capacity (it is dummy variable yes =1 , no=0) |
| Accessibility of agricultural extension services in the community | It concerns the availability of agricultural extension services in the community and it is dummy variable (yes =1 or no =0) yes =1 if the agricultural extension services are available in the local community (village) |
| Existing of Non-governmental organization or local associations in the community | It concerns the interventions of non. governmental organizations in the local community, it is a dummy variable (yes =1 if any intervention is realized by non-governmental organizations in the local community or village or no =1 otherwise) |
| Existing of producers 'organization in the community | It assesses the existence of producer's organizations run in the community and it is dummy variable , yes =1 if producer's organizations exist in the local community no=q otherwise |
| Existing of selling shop of fertilizers in the community | It concerns the availability of chemical fertilizers sellers in the local community or village , it is a dummy variable, yes =1 if there is fertilizers seller in the village no=0 otherwise |
| Access to agricultural loan in the | It concerns the access to agricultural credit in the community and assesses if the any program or |

| | |
|---|---|
| community ( dummy variable) | institutions provide agricultural credit to the inhabitants of the village, it is a dummy variable (yes =1 , no =0) |
| The distance to the extension center | It assesses the access to thenearest extension center and it is categorical variables, the categories are :Less than 5 kilometers, distance Between 5-10 kilometers, distance Between 10-20 kilometers, distance Above 20 kilometers |
| Age of household's head | It concerns how old is the household head in years , which could shows the accumulation of human and financial assets reliable for running economic activities, it is measured in number of years |
| Size of household | It concerns the number of people living in the household and is measured in number |
| Household income | It measures the total income of all member of household and it measured in Thousand Burundian International francs, the national currency unit. |
| Landholding per household | It is the area of household landholding and it is measured in hectare. |
| Agricultural production | It is the total of household agricultural production in equivalent cereals, fruit and vegetables are not included. |
| Access to local market | It assesses the access to local market centers and the capability to sell the output and participate in local trade, it is a dummy variable (yes =1 and no=0) |

Source: edited by author from Burundi National Agricultural Survey database 2011-2012, crop season B

### 3.3. Data sources

The data used in the study are from the micro-data of national agricultural survey 2011-2012 collected by the National Instituteof statistics. The used data in the analysis are those collected for the crop season B which lasts from March to June 2012, in which 52.2% of the national agricultural production is produced.

The data were collected using the multistage sampling methods. The data collection was the agricultural variables (agriculture input and output), and socio-economic and infrastructural situation of the community, the livestock and other income sources. The data collection does not include the fruit and vegetable and agricultural production under state management firms and per urban agricultural production.

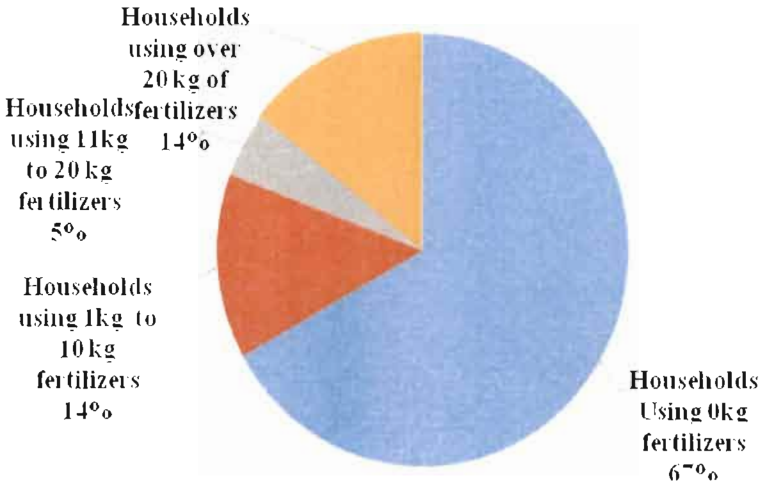
There were 16 rural provinces excluding the capital of the country for data collection by the National Instituteof statistics, and using multistage sampling and cluster sampling. Data collection was realized for 2560 households in which 160 households were interviewed for each of the 16 provinces. Each province was divided in 20 enumeration zones of 4 hills. In each hill was about 20 villages. Ten households were selected using the systematic draw method with equal probability. The questionnaire was administered to 8 households while the other 2 were reserved for replacement households.

## 4. Results of the study

### 4.1 Description of household's socio-economic characteristics

It is noticed that there is a low access to agricultural loan in the community, only 10.8% of the rural areas have been declared able to get agricultural loan. The access to extension is also quite low, only 8.8% of household's head has benefited from extension services. Nevertheless, extension services are accessible in the community for 89.5% of communities. Only 12.2% of the household heads participate in producers' organization activities and the access to local market is realized for only 34.6 % of the household. 24.2% of the household villages have access to fertilizer sellers in the village, which shows a low access to fertilizers' selling place.The usage of fertilizers analysis shows that only 35.2% of 1071 of households used fertilizers (Figure3).

**Figure 3 :Theuse of chemical fertilizers in agriculture (%)**




Source: Authors' Results, 2017

The analysis of the use of fertilizers shows that 67% of households do not use fertilizers, and only 33% use fertilizers, among them 14% use around 1 to 10 kilograms, 5% use 11-20 kilograms and14% of households use more than 20 kilograms.

**Table 2 Description of agricultural inputs and output**

| Variables | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|
| Agricultural Production in tons of equivalent cereals | 5.18 | 10.01 | 0 | 104.96 |
| Agricultural production in tons | 12.40 | 27.18 | 0 | 423.4 |
| Agricultural land per household in ha | 0.28 | 0.26 | 0 | 2.48 |
| Agricultural labor in hours | 7522.55 | 28751.64 | 0 | 611525.9 |
| Seeds in kilograms of equivalent cereals | 821.66 | 2186.249 | 0 | 26515 |

Source: Authors' Results, 2017

The average production in tons of equivalent cereals in the crop season B 2012 in the analyzed household is 5.18 tons and seeds employed are estimated at 821.6 kilograms of equivalents cereals. A small landholding is observed in Burundi agriculture in the analyzed household, the average of landholding is estimated at 0.28 ha per household.

### 4.2.1 Parameters estimation of stochastic frontier analysis of agriculture of Burundi

The one stage estimation method was used which allows obtaining the coefficients of stochastic frontier production and the estimates parameters of technical inefficiency in one step by using Stata13 software.

**Table 3: Model summary(equation :** $\ln(y_i) = \beta_0 + \beta_1 \sum_{i=1}^{s} \ln(x_i) + v_i - u_i$`)

| | |
|---|---|
| Stochastic frontier normal/half-normal model | Number of obs = 1071 |
| | Wald $Chi^2(3)$ = 250.56 |
| Log likelihood = -1485.0274 | Prob>$Chi^2$ = 0.0000 |

Source: Authors' Results, 2017

The results of the model show that the overall model is significant. Wald $Chi^2(3)$ = 250.56 and Prob>$Chi^2$ = 0.0000, which is less than 0.05 % and shows that the model is significant.

The average efficiency of the agriculture in Burundi in the crop season B of 2012 is estimated to 0.485, which shows a lower efficiency level in Burundi agricultural sector (Table 13). It can be noticed that it could be possible to double the production level, if the agricultural production efficiency is 100%. The determinants of inefficiency in the agricultural sector are done using the one stage stochastic frontier analysis method in Stata13.

**Table 4: The technical efficiency statistics (equation $TE_i = \exp(-\hat{}u_i) = TE_i = \frac{y_i}{f(x_i;\beta)e^{Vi}}$ equation : $\ln(y_i) = \beta_0 + \beta_1 \sum_{i=1}^{s} \ln(x_i) + v_i - u_i$**

| Variable | N | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|---|
| Technical efficiency | 1071 | 0.4817905 | 0.181108 | 0.0333041 | 0.8250815 |

Source: Authors' Results, 2017

### 4.2.2 Agricultural technical efficiency determinants

The analysis of the results of the stochastic frontier analysis of the agricultural production function shows that the agricultural land holdings, seeds and labor positively affect the agricultural production. The coefficients linked to these factors are significant at level of 1%. It is noticed that an increase of agricultural production is highly explained by an increase of agricultural land, while an increase of 1% of the land could influence 0.46% of the agricultural production. The effect of agricultural land to agricultural production is 15.9 and 9.16 times higher than the effect of seeds and labor to agricultural production, respectively.

The analysis of determinants of Burundi agricultural production inefficiency illustrates that the age of head of household, accessibility of household to road and marketplace, extension services, access to agricultural credit have a negative effect on agricultural inefficiency in Burundi for the study period of crop season B 2011-2012. The coefficients linked to physical accessibility extension canters less than

10 kilometers is significant at level of 1%, the age of household head is significant at level of 5% and the existence of access to a road in good condition in the community, access to local marketplace are significant at level of 10%.

#### 4.2.2.1 Age of head of household and agricultural inefficiency reduction

The age of household head is a positive factor to decrease the inefficiency in the agricultural sector in Burundi. This is somehow explained by the fact that the higher value of the production assets of older farmers are due to their capitalization and experience in agricultural production systems. It also shows the vulnerability of young farmers.

The age of head of household is related to the experience acquired in any specific field. The older a farmer is, the wiser the decisions taken are. The increase of 1year in household head is related to an increase of 0.0086 of agricultural efficiency. The young heads of agricultural household are more inefficient than the older household heads. This positive relationship between age and efficiency shows the lack of practical knowledge in agriculture of young farmer. It shows the importance of extension services of young farmers.

#### 4.2.2.2 Socio-economic infrastructure accessibility and agricultural inefficiency reduction

The analysis of the determinants of inefficiency has demonstrated that the closer a household is to the marketplace; it influences the reduction of its agricultural production inefficiency. It is also linked to the possibility of a household to be market-oriented and the possibility to change from the subsistence agricultural system to market-oriented agricultural system. For that, a market accessibility of household gives high economic incentives to rural farmers and economic reasoning in agricultural planning and management. Increasing the accessibility to local marketplace of 10% of the rural population could increase the efficiency to 0.7 %.

The access to road in good condition in the community led to the high economic exchange and improves the local trade of agricultural production. It is the positive factor that also stimulates the change of structure local economy from autarchy or closed economy to open economy, and exploitation of comparative advantage which may focus on improving competitiveness by increasing efficiency. Increasing the accessibility to road in good condition of 10% in rural areas is related to the increasing of agricultural efficiency at rate of 2.6 %.

#### 4.2.2.3 Access to extension services and efficiency enhancement

The extension services accessibility increases the efficiency of agricultural farmers by increasing the practical knowledge in agriculture. The extension center accessibility no far from 10kilometers enables the increase in agricultural efficiency of 0.47. It can be stipulated that the increase of accessibility to extension centers of 10% could increase agricultural efficiency of 4.7%.

#### 4.2.2.4 The role of agricultural credit in agricultural efficiency enhancement

The agricultural loan accessibility to farmers enables the acquisition of purchased agricultural inputs. The requirements to pay back the loan could also influence agricultural farmers who have got credit to manage their economic activities efficiently. The increased accessibility to agricultural credit for 1% of agricultural household is related to the increase in agricultural efficiency of 0.37%.

## 5 Conclusion and recommendations

The research analyses the determinants of the Burundian agricultural technical efficiency level in 2012 and the results of the stochastic frontier analysis revealed a low level of agricultural technical efficiency. The average technical efficiency of the Burundi agriculture was 0.48in 2012, which shows that the agricultural production could be doubled if the optimum technical efficiency were achieved. The agricultural technical efficiency improvement could be achieved by increasing access to road, local market, access to extension centers and agricultural credit.

Based on the findings of the study, the following recommendations and policy implications are possible to improve the rural well-being and poverty reduction by increasing rural income through agricultural efficiency improvement.

The policy targeting agricultural efficiency enhancement should be achieved by reducing the vulnerability of young farmers through supporting rural young farmers. The increasing economic empowerment of young farmers and female headed households should be promoted.

The young farmers' empowerment policy allows the decrease of agricultural inefficiency since the age of the household head has a positive influence on agricultural efficiency. The empowerment of rural young farmers' enhancement could be achieved by extensions, financial support, capacity building and economic activity management.

The policy related to the effect of increasing of agricultural landholding on income diversification should also be a concern since that an increase in agricultural landholding is unachievable in sustainable ways due to high agricultural population. The alternative solution might be an agricultural cooperation management and an increase in agricultural efficiency.

The policy makers should also focus on agricultural efficiency enhancement by facilitating access to market, accessibility of market information and support to the market efficiency of rural farmers. The increase of agricultural efficiency policy may also take increasing road networking into account. The access to road enables the local product transactions and increase access to agricultural product clients.

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**Appendixes**

**Table 1: Description of explanatory variables of stochastic frontier analysis**

| Variables | Categories | Frequency | percent |
|---|---|---|---|
| Sex of household head ( dummy variable) | Males | 1086 | 86.5% |
| | Females | 170 | 13.5% |
| Reading / writing skills of the Kirundi of head of household | Reading only Kirundi | 81 | 6.4% |
| | Reading and writing Kirundi | 744 | 59.2% |
| Reading / writing skills of the Kirundi of head of household | Reading skills of Other language only | 90 | 7.2% |
| | Reading and writing ( other language) | 247 | 19.7% |
| | No one of them | 919 | 73.2% |
| Belonging to Producer 'organization ( head of household | No | 1103 | 87.8% |
| | yes | 153 | 12.2% |
| Benefiting of extension (head of household) | No | 1145 | 91.2% |
| | Yes | 111 | 8.8% |
| Head of household has got credit in the last 3 years ( dummy variables ) | no | 1185 | 94.3% |
| | Yes | 71 | 5.7% |
| A road pass through the village | NO | 77 | 6.2% |
| | Yes | 1157 | 93.8% |
| good road in the community | No | 240 | 20.7% |
| | Yes | 918 | 79.3% |
| Access to local market | No | 790 | 64.4% |
| | Yes | 437 | 35.6% |

**Table 2: Description of explanatory variables of stochastic frontier analysis (continued )**

| Variables | Categories | Frequency | percent |
|---|---|---|---|
| Accessibility of agricultural extension services in the community | no | 129 | 10.5% |
| | Yes | 1103 | 89.5% |
| Existing of Non-governmental organization or local associations in the community | no | 693 | 56.3%% |
| | yes | 539 | 43.8%% |
| Existing of producers 'organization in the community | no | 233 | 18.9% |
| | yes | 998 | 81.1% |
| Existing of selling shop of fertilizers in the community | no | 934 | 75.8% |
| | yes | 298 | 24.2% |
| Existing of fertilizers sellers in the village | No | 934 | 75.8% |
| | yes | 298 | 24.2% |
| Access to agricultural loan in the community ( dummy variable) | no | 2240 | 89.2% |
| | Yes | 272 | 10.8% |
| The distance to the extension center | Less than 5 kilometers | 1616 | 64.5% |
| | Between 5-10 kilometers | 480 | 19.2% |
| | Between 10-20 kilometers | 288 | 11.5% |
| | Above 20 kilometers | 120 | 4.8% |

Source: edited by authors from Burundi National Agricultural Survey database 2011-2012, crop season B

**Table 3: Maximum likelihood estimates of Stochastic frontier analysis (equation :equation :** $\ln(y_i) = \beta_0 + \beta_1 \sum_{i=1}^{s} \ln(x_i) + v_i - u_i`)$ **where** $u_i$ln Seeds in Kilograms of equivalent Cereals),ln Agricultural labor in Hours),(ln Agricultural land per household in ha)$TE_i$

| Explanatory variables | Coefficients | Z | P>\|z\| |
|---|---|---|---|
| Lnseeds (ln Seeds in Kilograms of equivalent Cereals) | 0.029087 | 2.21 | 0.027** |
| lnLabor (ln Agricultural labor in Hours) | 0.0506021 | 3.12 | 0.002*** |
| lnLand (ln Agricultural land per household in ha) | 0.4636697 | 14.30 | 0.000*** |
| _constant | 3.016275 | 19.01 | 0.000*** |
| lnsig2v _cons | -0.7737577 | -5.72 | 0.000*** |

| **determinants of technical inefficiency ( equation :**$TE_i = P_0 + \sum_{i=1}^{n} P_i Z_i + \varphi_i$) | | | |
|---|---|---|---|
| Explanatory variables | Coefficients | Z | P>\|z\| |
| total household income in thousands of BIF | -1.40e-06 | - 0.03 | 0.973 |
| age of head of household in number of years | - 0.0085529 | - 2.00 | 0.046** |
| sex of household's head ( dummy variables male vs female) | 0.1618064 | 1.08 | 0.279 |
| reading skills of household head of national language (dummy variables | -0.0339978 | - 0.33 | 0.739 |

| | | | |
|---|---|---|---|
| reading at least or not) | | | |
| reading skills of household head of foreigner language (dummy variables reading at least or not ) | 0.008447 | 0.07 | 0.941 |
| participation in Producers' Organizations of head of household (dummy variable yes or no) | 0.0889214 | 0.38 | 0.703 |
| benefiting of extension by household's head (dummy variable yes or no) | -0.1824409 | -0.64 | 0.520 |
| household's head has got credit (dummy variable yes or no) | -0.2204586 | -0.70 | 0.481 |
| road available is in good condition | -0.264023 | -1.83 | 0.068* |
| access to local market place | -0.0714473 | -1.74 | 0.082* |
| accessibility to extension of the community | 0.2375512 | 1.11 | 0.266 |
| size of household | -0.0147296 | -0.57 | 0.570 |
| distance to nearest extension center | | | |
| between 5-10 kilometers | -0.4726289 | -2.80 | 0.005*** |
| between 10-20 kilometers | 0.0432239 | 0.22 | 0.828 |
| over 20 km | 0.4859222 | 1.55 | 0.121 |

| | | | |
|---|---|---|---|
| usage of fertilizers by the inhabitants of the community | 0.129601 | 0.85 | 0.395 |
| existing of fertilizers sellers in the village | -0.0261643 | -0.19 | 0.852 |
| access to agricultural loan in the local community | -0.3669234 | -1.79 | 0.073* |
| cons | 0.9232962 | 1.75 | 0.080* |
| sigma_v | 0.6791734 | | |

sigma_v | .6791734

dependant variable LnQ (ln Agricultural Production in Tons of equivalent cereals

Note: *** significant level at 1%, ** significant level at 5%, * significant level at 10%

Source: edited by authors from Burundi national agricultural survey database 2011-2012, crop season B