

3 **Analysis of Agricultural Efficiency in Burundi**

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6  
7 **Abstract**

8 The study aims at analysing of Burundi agricultural efficiency determinants. The results have  
9 shown a low level of agricultural efficiency. The agricultural efficiency level observed in  
10 Burundi agricultural sector showed a possibility of doubling the agricultural production using  
11 the same inputs by achieving the optimum efficiency. The determinants of agricultural  
12 efficiency enhancement included improving access to market, road, extension, agricultural  
13 loan and reduction of vulnerability of young and female farmers. A focus on agricultural  
14 efficiency enhancement might be prioritised to increase agricultural income.

15 **Keywords: Agricultural production, stochastic frontier, rural development**  
16

17 **1. INTRODUCTION**

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

24 Burundi is among the emerging countries and agriculture is the leading source of income,  
25 especially in rural areas where 88.2% of the population is living. Agriculture accounts for  
26 89% of the total workforce. The gross domestic product per capita is among the lowest in the  
27 world. It was 286 USD in 2014, and its annual growth was estimated to be at a rate of 1.3% in  
28 2014. The gross agricultural value added contributed at a rate of 43% to national gross  
29 domestic product in 2015 (World Bank Indicators, 2016)

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

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

42 In Burundi, the population is growing, and the agricultural holding area per household is  
43 decreasing each year. The arable land per capita is decreasing, it passed from 0.22ha per

44 capita in 1981 to 0.11ha per capita in 2014 (FAOSTAT database, 2016). Considering this  
45 decrease in the arable land per capita and increasing population, it can be assumed that the  
46 increasing agricultural productivity as the mayor economic sector could be one of the  
47 solutions to the problem.

48 It has been proven that a positive correlation exists between agricultural productivity  
49 improvement and poverty reduction (Mellor, 1999; Datt - Ravallion, 1998; Timmer, 1997;  
50 Byerlee *et al.*, 2009; Schneider - Gugerty, 2011; Rebati *et al.*, 2013). Schneider and Gugerty  
51 (2011) explained the existence of multiple pathways through which improvement of  
52 agricultural productivity can reduce poverty, and these include real income changes,  
53 employment generation, rural non-farm multiplier effects and food prices effects.

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

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

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

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

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## 70 **Objective and scope of the research**

71 Burundi is highly populated, with an estimation of population of 10.82 million in 2014 with  
72 88.2% living in rural areas; its projection in 2030 is 13.4 million (World Bank Indicators,  
73 2016). Although, 88.2% of the total population is in agriculture, the main sources of income  
74 in rural areas is agriculture, but its productivity does not allow rural people to get enough food  
75 and have high living standards. Based on that, it may be more indispensable to increase  
76 agricultural productivity. Considering the limit access on inputs, enhancement of agricultural  
77 production could be achieved through the realization enhancement of agricultural technical  
78 efficiency. That is why the analysis of agricultural technical efficiency could permit the  
79 exploration of the factors drive the increasing of technical efficiency and on which policy  
80 makers could focus on to improve agricultural productivity and standards of rural life.

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82 Considering the fact that agricultural sector is dominant in Burundi, the factors that permit  
83 the increasing of agricultural productivity are very interesting in the promotion of economic  
84 growth and rural development. The study aims to explore the elements that permit the  
85 enhancement of agricultural efficiency. The elements causing inefficiency in the agricultural  
86 household are analyzed. The main objective of the study is to analyze the determinants of

87 agricultural efficiency in Burundi. The study specifically aims to respond to the following  
88 research questions. The usage of secondary data of agricultural surveys (2011-2012) enables  
89 us to analyze:

- 90 1) Which efficiency level was observed in the agricultural sector in Burundi?
- 91 2) What determines agricultural efficiency in Burundi?
- 92 3) What factors have positive or negative impacts on the efficiency of Burundi's  
93 agriculture?

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## 95 2. LITERATURE REVIEW

### 96 2.1 Concepts of Production Efficiency

97 Efficiency farming is a kind of farming that requests fewer inputs than other to produce the  
98 agriculture output (Townsend *et al.*, 1998). Production efficiency analysis is based on  
99 production function, which is defined by the relation between the level of inputs and its  
100 related output (Schmidt, 1986) and is focused on the maximization of output under inputs  
101 constraint or minimization of inputs for a certain level of output (Besanko - Braeutigam,  
102 2005). The frontier analysis is based on the technological relationships between inputs and  
103 outputs specified in the production function as mentioned above:

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

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

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

112 A. Through *horizontal approach* which consists of an increase in inputs used in production.  
113 However, input increasing is realizable if either the price of inputs is decreasing or when  
114 increasing output price

115 B. Through *improvement approach* which is connected to the role of improvement of socio-  
116 economic, institutional and environmental constraints to the enhancement of production  
117 taking unchangeable the existing level of inputs.

118 C. Through *technological enhancement of production* which includes improved production  
119 techniques, using modern and improved seed, modern fertilizer and chemicals and it is usually  
120 termed as a transformation approach (Alene, 2003).

121 In an analysis of efficiency, we need to catch the difference between productivity, which  
122 indicates the ratio of output (s) to inputs, while efficiency indicates the highest productivity  
123 level from each input level (Coelli *et al.*, 1998). It is distinguished technical efficiency, which  
124 is related to physical inputs minimization or physical outputs maximization productivity;  
125 allocative efficiency, which is related to the right use of mixing input regarding the relative

126 price of each price (input allocative efficiency) or the production of the right mix of output  
127 given their relative prices (output allocative efficiency) (Kumbhaker - Lovell, 2000). The  
128 economic (overall) efficiency is achieved for a firm which realizes the technical and allocative  
129 efficiency.

130 The graphical illustration of these two concepts is by using a simple example of two inputs  
131 ( $x_1, x_2$ ) – two outputs ( $y_1, y_2$ ), production. The efficiency is considered if the optimal  
132 combination of inputs is used for a given level of output (an input-orientation) or the optimal  
133 output production given a set of inputs (output-orientation).

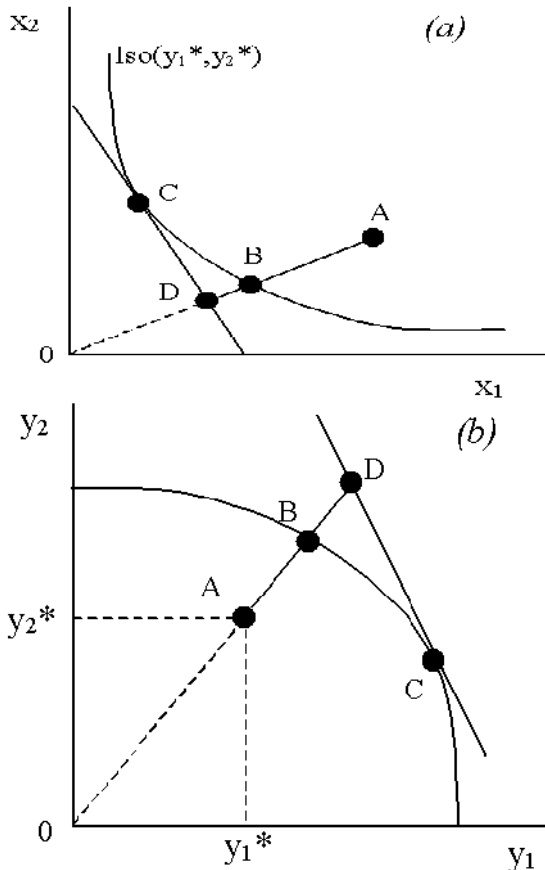
134 In **Figure 1A**, the mix of input use allows the firm to produce a given level of output ( $y_1^*, y_2^*$ ),  
135  $y_2^*$ ). The production of same level output could have been realized by the use of mixing fewer  
136 inputs represented by the point 'b', which is on the isoquant actually representing the  
137 minimum level of inputs required for ( $y_1^*, y_2^*$ ) production, in figure Iso( $y_1^*, y_2^*$ ).

138  $OB/OA$  determined the input-oriented level of technical efficiency designed ( $TE_i(y,x)$ ), whereas  
139 the production ( $y_1^*, y_2^*$ ) with the least cost combination of input is given by the point 'C' (the  
140 point, where the marginal rate of technical substitution between the factors of production is  
141 equal to their relative price ratio  $w_2/w_1$ ). In order to attain the usage of the same level of cost  
142 of input in production, we need to reduce the inputs to point 'D'.

143 The cost efficiency ( $CE(y,x,w)$ ) is determined by the ratio  $OD/OA$ , and then  
144  $CE(y,x,w)/TE_i(y,x)$ , or  $OD/OB$ . **Figure 1A** indicates the input allocative efficiency  
145 ( $AE_i(y,w,w)$ ) (Kumbhaker - Lovell, 2000)

146 The output orientation of the maximization of production is figured by the production  
147 possibility frontier for a given set of inputs (see **Figure 1B**). The production obtained at the  
148 point could be augmented to point b if an efficient use of input is realized. Therefore, the  
149 output oriented maximization given by the attainment of technical efficiency ( $TE_o(y,x)$ ) is  
150 given by the ratio of  $OA/OB$ . This situation is the equivalent of the input oriented measure of  
151 technical efficiency in the situation of constant returns to scale whereas point 'B' indicates  
152 technical efficiency due to the fact that it lies on the production possibility frontier and the  
153 higher revenue is realized at point 'C' where the marginal rate of transformation between the  
154 input is equal to the inverse of the price ratio  $p_2/p_1$ . In order to get the same level of revenue  
155 as the one at point 'C' while the combination of output and input is unchanged, the output of  
156 the firm need to be augmented to point 'D'. Consequently, the efficiency revenue ( $RE(y,x,p)$ )  
157 is given by the ratio  $OA/OD$  determining the efficiency revenue ( $RE(y,x,p)$ ) and  
158  $RE(y,x,w)/te_i(y,x)$ , or  $OB/OD$  in **figure 1B** gives the output allocative efficiency  
159 ( $AE_o(y,w,w)$ ). (Kumbhaker and Lovell, 2000)

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

Source: Herrero- Pascoe, 2002

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## 2.2 Measurement of technical efficiency

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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.

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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).

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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*

185 *production of a firm is bounded above by the sum of a parametric function of known inputs,*  
186 *involving unknown parameters, and a random error, associated with measurement of the level*  
187 *of production or other factors, such as the effects of weather, strikes, damaged product, etc.*  
188 *The greater the amount by which the realized production falls short of this stochastic frontier*  
189 *production, the greater the level of technical inefficiency”.*

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

197 In the following Figure 2, we assume that two farm households a and b use  $x_a$  and  $x_b$  inputs,  
198 respectively, to get and their outputs  $q_a$  and  $q_b$  shown by the illustration. The observed values  
199 represent the frontier values which is the situation of lack of inefficiency in production (in  
200 case where  $u_A = 0$  and  $u_B = 0$ ) and then the frontier level of output is determined by the  
201 function  $\ln(q_A) = \beta_A X_A + v_A$  and function  $\ln(q_B) = \beta_B X_B + v_B$  for these two farms a  
202 and b. In the illustration it is also clear that the frontier output for the household a is above the  
203 deterministic level of output due to the positive noise effects ( $v_A > 0$ ), and for the producer b  
204, its frontier output lies below the deterministic level of output caused by the negative noise  
205 effects ( $v_B < 0$ ) (Coelliet al., 2005).

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254 possibility to increase agricultural output without additional inputs given the existing  
255 technology It has also been noticed that most studies reviewed tried to explain farm  
256 level variation technical efficiency using mostly as variables farm education and  
257 experience, contacts with extension and access to credit and farm size. Except the farm  
258 size, all results showed that these variables tended to have a positive and statistically  
259 significant impact on technical efficiency.

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

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### 270 **3. MATERIAL AND RESEARCH METHODS**

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#### 271 **3.1. Data sources**

272 The data used in the study are from the micro-data of national agricultural survey 2011-2012  
273 collected by the National Institute of Social and Economic studies. The used data in the  
274 analysis are those collected for the crop season B which lasts from March to June 2012, in  
275 which 52.2% of the national agricultural production is produced.

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

281 There were 16 rural provinces excluding the capital of the country for data collection by the  
282 National Institute of Social and Economic studies, and using multistage sampling and cluster  
283 sampling. Data collection was realized for 2560 households in which 160 households were  
284 interviewed for each of the 16 provinces. Each province was divided into 20 areas of  
285 enumeration of 4 hills and in these 4 hills 20 villages. Ten households were selected using the  
286 systematic draw method with equal probability. The questionnaire was administered to 8  
287 households while the other 2 were reserved for replacement households.

#### 288 **3.2. Theoretical framework of the study**

289 Production efficiency analysis methods

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

296 The stochastic frontier production function is specified as;

$$297 \quad y_i = f(x_i; \beta) e^{v_i} TE_i ,$$

298 Where  $y_i$  indicates the  $i^{\text{th}}$  household's output and  $x_i$  the combination of inputs utilized in  $i^{\text{th}}$   
299 household's output the production.

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

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

$$311 \quad TE_i = \frac{y_i}{f(x_i; \beta) e^{v_i}} \quad \text{where } 0 \leq TE_i \leq 1$$

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

$$314 \quad \text{Cobb Douglas: } \ln(y_i) = \beta_0 + \beta_1 \sum_{i=1}^s \ln(x_i) + v_i - u_i$$

$$315 \quad \text{Translog: } \ln(y_i) = \beta_0 + \sum_{k=1}^s \beta_k \ln(x_{ik}) + \frac{1}{2} \sum_{k=1}^s \sum_{j=1}^s \beta_{ij} \ln(x_{ik}) * \ln(x_{ij}) + v_i - u_i$$

316 Where  $\ln(x_{ij})$  is the natural logarithmic transformation,

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

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

$$325 \quad E_i = f(u; \varepsilon) du = \frac{2}{2\pi\sigma_u\sigma_v} \exp\left\{-\frac{u^2}{2\sigma_u^2} - \frac{(\varepsilon+u)^2}{2\sigma_v^2}\right\} = \frac{2}{\sigma} \phi\left(\frac{\varepsilon}{\sigma}\right) \left[1 - \Phi\left(\frac{\varepsilon\lambda}{\sigma}\right)\right]$$

326 for  $-\infty < E_i < \infty$

327 and where  $\sigma^2 = \sigma_u^2 + \sigma_v^2$  and  $\lambda = \frac{\sigma_u}{\sigma_v}$  are variance parameters and  $\phi(\cdot)$  Indicates the standard  
328 probability density function and  $\Phi(\cdot)$  represents the standard cumulative density function.  
329 Kumbhakar and Lovell (2000) stated that  $\lambda$  in the above equation indicates the relative  
330 contribution of  $u_i$  and  $v_i$ , respectively to  $\varepsilon_i$ . Therefore, if  $\lambda \rightarrow 0$ , either  $\sigma_v^2 \rightarrow \infty$  or

331  $\sigma_u^2 \rightarrow 0$ , and in this case a situation occurs, where the symmetric error  $v_i$  dominates the  
 332 inefficiency part  $u_i$  and, if  $\lambda \rightarrow \infty$  either  $\sigma_v^2 \rightarrow 0$  or  $\sigma_u^2 \rightarrow \infty$ , in this case,  $u_i$  dominates  $v_i$  in  
 333  $\varepsilon_i$ .

334 Considering the marginal distribution in the former equation of  $\varepsilon_i$ , the further step is to form  
 335 and maximize the likelihood function concerning  $\beta, \sigma^2$  and  $\lambda$ . In order to estimate the  
 336 unknown coefficients of the parameters and then the measure of inefficiency  $u_i$  nevertheless,  
 337 the decomposition of error  $\varepsilon_i$  in  $u_i$  and  $v_i$  is not realizable. To get the solution a conditional  
 338 distribution of  $u_i$  might be considered that was first introduced by Jondrow *et al.* (1982)  
 339 expressed as follows:

$$E(u_i / \varepsilon_i) = \hat{u}_i = \frac{\sigma\lambda}{1 + \lambda^2} \left[ \frac{\left(\frac{\varepsilon\lambda}{\sigma}\right)}{1 - \varphi\left(-\frac{\varepsilon\lambda}{\sigma}\right)} - \left(\frac{\varepsilon\lambda}{\sigma}\right) \right]$$

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

$$TE_i = \exp(-\hat{u}_i)$$

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

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

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

$$U_i = P_0 + \sum_{i=1}^n P_i Z_i + \varphi_i$$

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

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

366 estimation of determinants of technical inefficiency will be done by using the one stage  
 367 estimation method.

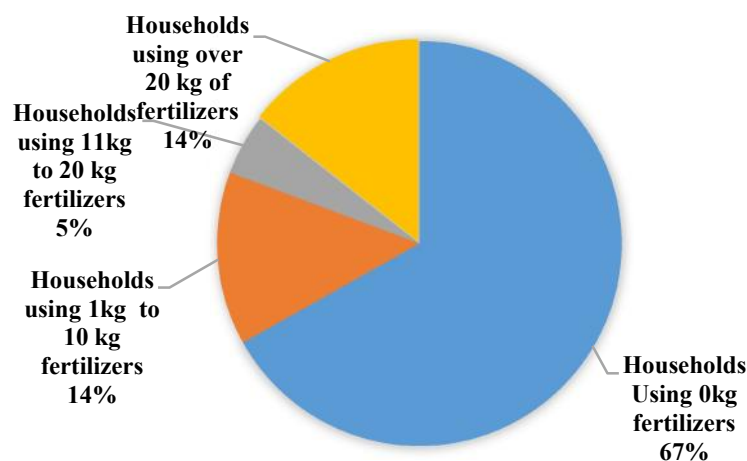
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## 369 4. RESULTS OF THE STUDY

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### 371 4.1 Description of household's socio-economic characteristics

372 It is noticed that there is a low access to agricultural loan in the community, only 10.8% of the  
 373 rural areas have been declared able to get agricultural loan. The access to extension is also  
 374 quite low, only 8.8% of household's head has benefited from extension services.  
 375 Nevertheless, extension services are accessible in the community for 89.5% of communities.  
 376 Only 12.2% of the household heads participate in producers' organization activities and the  
 377 access to local market is realized for only 34.6 % of the household. 24.2% of the household  
 378 villages have access to fertilizer sellers in the village, which shows a low access to fertilizers'  
 379 selling place. The usage of fertilizers analysis shows that only 35.2% of 1071 of households  
 380 used fertilizers (Figure 3).



381

382 **Figure 3: The use of chemical fertilizers in agriculture (%)**

383 Source: Authors' Results, 2017

384

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

### 388 4.2 Technical efficiency Outputs

389 The technical efficiency of agriculture is estimated using one stage the stochastic  
 390 frontier analysis method. The inputs were selected the Cobb Douglas production  
 391 function Cobb Douglas:  $\ln(y_i) = \beta_0 + \beta_1 \ln(x_1) + \beta_2 \ln(x_2) + \beta_3 \ln(x_3) + v_i$

392 The agricultural inputs considered for the technical efficiency analysis are composed by the  
 393 agricultural land measured in hectare, which is the basis of the agricultural production, the  
 394 labor measured in hours of work that household workforce, paid and non-paid workforce are  
 395 spent on agricultural and so related activities (examples as carriage of agricultural inputs and  
 396 production), seeds in equivalent cereals. The study did not take into consideration the  
 397 fruits and vegetables. The households with available data for stochastic frontier  
 398 analysis were estimated to 1,071.

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401 **Table 1 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

402 Source: Authors' Results, 2017

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

407

408 **4.2.1 Parameters estimation of stochastic frontier analysis of agriculture of Burundi**

409 The Parameter estimates of the stochastic production frontier model and technical inefficiency  
410 model were obtained using the maximum likelihood estimation methods. The one stage  
411 estimation method was used which allows obtaining to get in one step the coefficients of  
412 stochastic frontier production and the estimates parameters of inefficiency in one step by  
413 using Stata13 software.

414

415 **Table 2: Model summary**

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

416 Source: Authors' Results, 2017

417

418 The results of the model show that the overall model is significant. Wald Chi<sup>2</sup>(3) = 250.56  
419 and Prob>Chi<sup>2</sup> = 0.0000, which is less than 0.05 % and shows that the model is significant.  
420 The number of observation is 1,071, which is quite acceptable for a maximum likelihood  
421 estimation method.

422 The average efficiency of the agriculture in Burundi in the crop season B of 2012 is estimated  
423 to 0.485, which shows a lower efficiency level in Burundi agricultural sector (Table 3). It can  
424 be noticed that it could be possible to double the production level, if the agricultural  
425 production efficiency is 100%. The determinants of inefficiency in the agricultural sector are  
426 done using the one stage stochastic frontier analysis method in Stata13.

427

428

429

430 **Table 3: The technical efficiency statistics**

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

431 Source: Authors' Results, 2017

432

433 **4.2.2 Agricultural technical efficiency determinants**

434 The analysis of the results of the stochastic frontier analysis of the agricultural production  
 435 function shows that the agricultural land holdings, seeds and labor positively affect the  
 436 agricultural production. The coefficients linked to these factors are significant at level of 1%.  
 437 It is noticed that an increase of agricultural production is highly explained by an increase of  
 438 agricultural land, while an increase of 1% of the land could influence 0.46% of the  
 439 agricultural production. The effect of agricultural land to agricultural production is 15.9 and  
 440 9.16 times higher than the effect of seeds and labor to agricultural production, respectively.

441 The analysis of determinants of Burundi agricultural production inefficiency illustrates that  
 442 the age of head of household, accessibility of household to road and marketplace, extension  
 443 services, access to agricultural credit have a negative effect on agricultural inefficiency in  
 444 Burundi for the study period of crop season B 2011-2012. The coefficients linked to physical  
 445 accessibility extension canter less than 10 kilometers is significant at level of 1%, the age of  
 446 household head is significant at level of 5% and the existence of access to a road in good  
 447 condition in the community, access to local marketplace are significant at level of 10%.

448 **4.2.2.1 Age of head of household and agricultural inefficiency reduction**

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

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

459

460 **4.2.2.2 Socio-economic infrastructure accessibility and agricultural inefficiency**  
 461 **reduction**

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

469 The access to road in good condition in the community led to the high economic exchange

470 and improves the local trade of agricultural production. It is the positive factor that also  
471 stimulates the change of structure local economy from autarchy or closed economy to open  
472 economy, and exploitation of comparative advantage which may focus on improving  
473 competitiveness by increasing efficiency. Increasing the accessibility to road in good  
474 condition of 10% in rural areas is related to the increasing of agricultural efficiency at rate of  
475 2.6 %.

#### 476 **4.2.2.3 Access to extension services and efficiency enhancement**

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

#### 482 **4.2.2.4 The role of agricultural credit in agricultural efficiency enhancement**

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

488

## 489 **5 CONCLUSION AND RECOMMENDATIONS**

490

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

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

501

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

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

511 The policy related to the effect of increasing of agricultural landholding on income

514 diversification should also be a concern since that an increase in agricultural  
515 landholding is unachievable in sustainable ways due to high agricultural population.  
516 The alternative solution might be an agricultural cooperation management and an  
517 increase in agricultural efficiency.

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

523

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627 **APPENDIXES**

628

**Table 1: The description of the variables of the study**

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<b>Variables</b>	<b>Description</b>
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)
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)

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**Table 1: The description of the variables of the study( continued)**

<b>Variables</b>	<b>Description</b>
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 organisations run in the community and it is dummy variable , yes =1 if producer's organisations exist in the local community no=q otherwise
Existing of selling shop of fertilisers in the community	It concerns the availability of chemical fertilisers sellers in the local community or village, it is a dummy variable, yes =1 if there is fertilisers seller in the village no=0 otherwisem
Access to agricultural loan in the community ( dummy variable)	It concerns the access to agricultural credit in the community and assesses if any program or 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 the nearest 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.

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

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**Table 2: Description of explanatory variables of stochastic frontier analysis**

<b>Variables</b>	<b>Categories</b>	<b>Frequency</b>	<b>percent</b>
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 skills of Other language only	90	7.2%
Reading / writing skills of the Kirundi of head of household	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%

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

<b>Variables</b>	<b>Categories</b>	<b>Frequency</b>	<b>percent</b>
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%

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

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**Table :3 Maximum likelihood estimates of Stochastic frontier analysis**

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***

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<b>determinants of technical inefficiency</b>			
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 reading at least or not)	-0.0339978	-0.33	0.739
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		

649 sigma\_v | .6791734

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

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

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