

Determinants of the Technical Efficiency of Maize Farmers in Burkina Faso

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Résumé

La présente étude analyse les déterminants de l'efficacité technique des producteurs de maïs au Burkina Faso. La frontière stochastique de la fonction de production Translog a été utilisée à partir de données en coupe instantanée de 275 producteurs. Les résultats montrent que les producteurs de maïs ont un score d'efficacité technique moyen de 0,83. Ce qui signifie que les exploitants de maïs produisent à 83% de leur capacité productive, et peuvent ainsi atteindre le niveau de leur production potentielle en accroissant leur efficacité technique de 17% sans utilisation supplémentaire de facteurs de production. L'âge de l'exploitant, le sexe, la taille du ménage, l'utilisation de semences améliorées de maïs, et de la fumure organique ont été identifiés comme facteurs explicatifs de l'efficacité technique des producteurs de maïs dans la zone d'étude. En conséquence, toute politique d'amélioration des niveaux d'efficacité technique des producteurs de maïs au Burkina Faso doit nécessairement s'appuyer sur ces variables.

Mots clés: efficacité technique, fonction stochastique, fonction translog, maïs, Burkina Faso

Abstract

This study aims to analyze the determinants of the technical efficiency of maize farmers in Burkina Faso. The stochastic frontier of the translog production function was used from cross-sectional data of 275 farmers. The results show that maize farmers have a score of technical efficiency average of 0.85. This means that maize farmers produce 83% of their production capacity, and can reach the level of their potential production by increasing their technical efficiency of 17% without additional use of production factors. The age of the farmer, the gender, the size of the household, the use of improved maize seeds and organic fertilizers have been identified as factors explaining the technical efficiency of these maize farmers in the area of study. Consequently, any policy aiming to improve the technical efficiency of maize farmers in Burkina should be based on these variables.

Keywords: technical efficiency, stochastic frontier function, translog function, maize, Burkina Faso

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1. Introduction

The sustainable increase of agricultural productivity and more particularly that of cereal production constitutes one of the major challenges in terms of agricultural development in Burkina Faso. This is due to the fact that cereals are the food base of the population and contribute to more than 60% of the calorific needs of the population (DGPER 2012). However, in Burkina Faso, like many African countries, the extensive nature of cereal production suggests inefficiency in the adoption and use of technological innovations. Despite efforts to popularize new farming techniques in recent years, the rate of growth in cereal production remains low. One possible solution for the sustainable increase in agricultural production is to increase the productivities of the factors of production by increasing the technical efficiency of the farmers and / or through technological improvements (kumbhakar et Lovell, 2000 ; Nkamleu, 2004 ; Combarry et Savadogo, 2014). Technical efficiency therefore refers to the ability of the farmer to produce the maximum possible output given the resources or the quantities of factors available. Thus, improving the technical efficiency of farmers by intensifying agricultural production is essential for food security in Burkina Faso. Given these findings, it is important to analyze the factors determining the technical efficiency of grain farmers in Burkina Faso in order to formulate recommendations for sustainable agricultural development. The choice of this work is focused on maize because of the place it occupies in terms of food, employment and income. Indeed, maize is part of the food base of a large proportion of the population. It contributes to meeting heating needs by 19% and accounts for 30% and 12% of household consumption expenditure for cereals respectively in urban and rural areas in Burkina Faso. This has resulted in an increase in maize production. This paper therefore proposes an analysis of the determinants of the technical efficiency of maize farmers in Burkina Faso. This work presents the framework of econometric analyzes of efficiency, the

analysis of research results and the implications in terms of agricultural economic policies.

2. Framework for analysis of efficiency

This research is based on the microeconomic grounds of the producer theory. According to the microeconomic theory, the economic agent seeks to maximize its utility or profit depending on whether it is a consumer or a producer under constraint of consumer income or technology respectively. Indeed, production is the act of transforming inputs into outputs or products. The way in which inputs must be combined to obtain the maximum output will lead researchers to focus on the analysis of the efficiency of farmers presented in the next section.

2.1. Notion of efficiency

According to the microeconomic basics, the measure of efficiency has no reason to be because under the assumption of rationality of economic agents, the producer always produces at its optimal level given the inputs available to it. However, the differences with the actual facts led researchers from the 1950s to focus on the measurement of efficiency and factors determining the efficiency or inefficiency of producers. Thus, it is in the works of Koopmans (1951) with the analysis of production and Debreu (1951) with the introduction of the use of resources that appeared the measure of efficiency. Efficiency has two main components: technical efficiency and allocative efficiency. This decomposition is done by Farrell (1957) for the estimation of production frontiers.

Technical efficiency measures the way in which an operation combines the quantities of inputs that enter the production process given the proportions of the factors (Farrell 1957). For Porcelli (2009), technical efficiency is measured by the difference between the observed output quantities and the maximum or optimal output, the quantity of production factors being fixed. And, alternatively, it is the gap between the inputs observed or actually used for production and the minimum level of inputs needed to produce a given level of output. For this purpose, a farmer is said to be technically efficient when producing as much as possible, the quantity of factors of production being fixed, or when he uses as few factors as possible to produce a given level of output. According to Koopmans (1951), an operator is technically efficient, if for a given level of factors and profits it is impossible to increase the quantity of a product without increasing the quantity of one or more factors, or without reducing the quantity of another product. This definition is relatively equivalent to an optimal Pareto equilibrium situation. As a result, an operator is technically efficient if he is on his optimal production frontier. In the same vein, Nyemeck and Nkamleu (2006) state that the farmer is considered efficient if, given the quantity of inputs used, the level of production is such that it is impossible to exceed it.

As for allocative or price efficiency, it refers to the ability of the firm or farmer to combine inputs and outputs in optimal proportions relative to market prices, which is assumed to be competitive (Farrell, 1957; Leibenstein, 1966, Piot-Lepetit and Rainelli, 1996, Adegbola et al, 2006). The measure of allocative efficiency is obtained by the difference between the minimum cost of production of a given level of output and the actual cost of production realized by the firm or the farmer. According to the microeconomic foundations of the theory of the farmer, at the optimum the marginal rate of substitution between each pair of factors of production is equal to the proportion of the price of the latter. Thus, the production process is allocative efficient if it reaches this optimum.

In addition, in a production process, when the farmer is both technically and allocative efficient, it is said that there is economic efficiency. Farrell (1957) defines it as the product of technical efficiency and allocative efficiency. This efficiency refers to the concepts of productivity, performance, quality and profit on the one hand, and the reduction of the force employed and the costs on the other hand (Coelli 1998, Amara and Robert 2000, Ouattara 2012).). Thus, an economically efficient farmer produces at his maximum level, at a minimal cost of production factors and thus achieves maximum profit.

2.2. The production frontier

Any measurement of the technical efficiency of an economic activity necessarily implies the preliminary determination of the frontier of production. Indeed, this frontier represents the set of points indicating the maximum quantity of products that can be obtained for a given volume of inputs. In other words, the production frontier is obtained by the set of points describing the optimal decisions (outputs-inputs) of the farmers. Several models of production frontiers have been developed on the basis of the work of Farrell (1957). These models can be grouped into two fundamental approaches, including the non-parametric approach proposed by Charnes et al. (1978) and the parametric approach proposed by Aigner and Chu (1968), Aigner et al. (1977) and Meeusen and Van Den Broeck (1977). The parametric frontier is based on a specific functional form of production whereas the non-parametric frontier does not impose a functional form of the model (Boris Bravo-Ureta and Antonio Pinheiro, 1993). The non-parametric approach is said to be deterministic because according to this approach any difference between the actual production and the optimal production is explained by the inefficiency of the farmer. However, the parametric approach can also be deterministic or stochastic. It is stochastic when the gap is explained by the inefficiency of the farmer on the one hand and by random factors beyond his control or statistical errors on the other (Kumbhakar and Lovell, 2000).

In this research, the stochastic parametric frontier is used to better divide the inefficiencies that are directly incumbent on maize farmers and those explained by exogenous factors (climate, rainfall, pests ...) or errors in statistical measurements. Tchale and Sauer (2007) believe that the stochastic frontier is appropriate for measuring efficiency in the agriculture sector since it is largely influenced by exogenous shocks. In the same vein, Ouattara (2012) adds that the differences are not only explained by the farmer but they come from the inefficiency of the farmer as well as the factors that are uncontrollable to him and the errors of statistical measurements.

2.3. Basic model of the stochastic production frontier

Aigner et al. (1977), Meeusen and Van den Broeck (1977) are precursors of the stochastic frontier model, which has been improved in the work of Jondrow (1982). They have developed stochastic frontier models characterized by three components, namely the deterministic component of the production function, measurement or random errors and inefficiency errors. This decomposition of the error term into two components explains the name of "composite error models" often attributed to stochastic frontier models. The structural form of the stochastic production frontier proposed by Battese and Coelli (1995) is represented by the following formula:

$$y_i = f(x_i; \beta) \exp(\varepsilon_i) \quad (1)$$

with $\varepsilon_i = v_i - u_i$ and $i = 1, 2, \dots, n$ and y_i the output of the i -th farmer

$f(\cdot)$: the production function

x_i : a $(1 \times K)$ input vector and β a $(K \times 1)$ vector parameters.

ε_i : the error term which is decomposed into:

v_i : a random error term that accounts for measurement errors and other factors that are not under the control of the farmer and follows a truncated normal distribution $N(0, [\sigma_v^2])$.

u_i : an asymmetric non-negative random error term that measures technical inefficiency and follows a normal distribution of parameters $N(\mu, [\sigma_u^2])$.

v_i and u_i are independent of each other and independent of the explanatory variables. So we have:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \quad (2) \quad \text{et} \quad \gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \quad (3) \quad \text{avec } \gamma \in [0; 1]$$

Battese and Corra (1977) define σ^2 and γ as the contribution of technical efficiency to production. σ^2 being the sum of the variance of the term representing inefficiency and that of the random term and γ measuring the share of the inefficiency term in the total variance. These parameters are estimated by the Maximum Likelihood method. $\gamma = 0$ means that there is no stochastic technical inefficiency.

The level of technical efficiency of the i -th farmer is obtained by the ratio between the observed production frontier (y_i) taking into account the input levels used by this farmer and the stochastic production frontier (y_i^*). The technical efficiency (ET) of the farmer can be measured by:

$$ET_i = \frac{y_i}{y_i^*} = \frac{f(x_i; \beta) \exp(v_i - u_i)}{f(x_i; \beta) \exp(v_i)} = \exp(-u_i) \quad \text{pour } 0 \leq ET \leq 1 \quad (4)$$

In other words, the technical efficiency index can be calculated as an estimate of the conditional mean of data. According to Kumbhakar and Lovell (2000), we have:

$$ET_i = E[\exp(-u_i) | \varepsilon_i] = \left[\frac{1 - \Phi\{\sigma_i^* - (\mu_i^*/\sigma_i^*)\}}{1 - \Phi\{-(\mu_i^*/\sigma_i^*)\}} \right] \exp\left(-\mu_i^* + \frac{1}{2}\sigma_i^{*2}\right) \quad (5)$$

Where $\mu_i^* = \frac{\mu\sigma_v^2 - u_i\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \quad (6) \quad \sigma_i^{*2} = \frac{\sigma_v^2\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \quad (7)$

$\Phi(\cdot)$ representing the cumulative distribution function

Technical inefficiency is estimated by $1 - E[\exp(-u_i) | \varepsilon_i] \quad (8)$

2.4. Determinants of technical efficiency

The stochastic frontier of production efficiency analysis originally proposed by Aigner et al. (1977) and Meeusen and Van den Broeck (1977) have therefore been very successful both in its use in the field of research and in its ability to produce results, especially in the agricultural field. This is because this analysis is a tool for agricultural policies to improve factor productivity and the level of production. Thus, on the basis of the work of the precursors of the stochastic production function analysis, above-mentioned, several authors have been interested in identifying the determinants of the efficiency of the farmers. In accordance with the work of Battese and Coelli (1995), Balcombe et al. (2008) and Nuama (2010), the determinants of technical efficiency generally used in agriculture are credit, farm management, the number of years of experience of the farmer, his age, his level of education, farm size and mutual help.

In addition, the effects of some of these factors, such as credit and education, on farmers' performance have been controversial. For some researchers, they improve agricultural productivity; for others, they have no effect on the technical efficiency of agricultural farmers.

According to Coelli and Fleming (2004), the instruction evaluated in terms of number of years of study is a

variable that should positively affect the efficiency of farmers in the sense that an educated farmer easily masters modern farming techniques production. But, the works of Gurgand (1993) and Audibert et al. (1999) have shown the opposite. For them, the most educated households reduce the part of agriculture in their activities, to focus on jobs they consider more remunerative or more prestigious. In addition, Kalaitzandonakes and Dunn (1995) analyzed the relationship between technical efficiency, managerial capacity and farmer education in maize production in Guatemala. From a sample of 82 farmers and estimating the production frontier from three alternative methods, they conclude that the effect of education on efficiency is partly due to the measurement strategies of the efficiency and education. The use of the two-step method also gives different results depending on whether it is a stochastic or deterministic function.

According to Nuama (2010), access to credit increases farmers' efficiency by increasing their ability to take risks. Credit therefore allows the acquisition of expensive inputs that are necessary for production. Thus, credit positively influences the efficiency of the farmers, if the funds obtained by the farmers through the loan structures are used for the purchase of modern inputs. The positive effect of credit on farmer efficiency has been obtained in the work of several other authors including Albouchi et al (2007); Tchale and Sauer (2007), Combarry. and Savadogo (2014). However, the empirical work of Nyemeck et al. (2004) and Helfand and Levine (2004) have shown that credit, if used for other purposes, may not have an expected effect on agricultural performance.

In addition, other factors besides those currently analyzed, are increasingly integrated in the analysis of the sources of efficiency of the farmers according to the objective of the studies. These include technology or production factors such as the use of organic fertilizer, improved seeds, animal traction, household type ... For example, Chirwa (2003) analyzed the technical efficiency of small animals' farmers in Malawi and has an average efficiency score of 53%. The size of the farm, the hired labor force, the use of hybrid seeds and the membership of a farmers' organisation have been identified as favoring the efficiency of farmers. Adégbola et al. (2006) studied efficiency in rice systems in Benin. Based on a sample of 165 farmers, they identify the use of herbicides, animal traction and improved varieties as determinants of farmer efficiency.

Some authors have already discussed the issue of technical efficiency in Burkina Faso agriculture. For example, Kaboré (2007) analyzed the technical efficiency of rice production on the developed perimeters of Burkina Faso. The results show that rice farmers in the developed areas of Burkina are 83% efficient in the Kou and Sourou valleys and 76% in Bagré. He integrates the household type into his analysis and finds that a large household is more efficient than a nuclear-type household in the Kou Valley and less efficient in the Bagré. Also, Combarry and Savadogo (2014) analyzed the sources of growth in total factor productivity in Burkina Faso's cotton farms. They show that this growth is based on the improvement of the allocative and technical efficiency, which is explained by the agricultural credit, the number of assets and the age of the assets. The purpose of this paper is to analyze the efficiency of Burkina Faso maize farmers in order to highlight the specificities of Burkina Faso for a better orientation of government actions for the sector.

3. Operational framework and econometric efficiency estimation strategies

3.1. Data source and descriptive statistics

3.1.1. Presentation of the data and the study area

The data used in this research are secondary data of the ministry in charge of agriculture of Burkina, in particular through the statistical service. These data are derived from the 2012 Permanent Agricultural Survey (PAS). This survey covers the forty-five (45) provinces of the country. Its main objectives are to estimate the production of the provinces and the country for each crop by determining the areas cultivated by crop and the average production per unit area (yield), and to follow the evolution of the food situation of Burkina.

In this study, the largest areas in terms of maize production, the Boucle du Mouhoun, Cascades, Center West and Hauts Bassins (MASA, 2013) were selected for analysis. Maize cultivation is mainly practiced in rainfed, but there is a gradual evolution in the production of irrigated maize. In this zone, there are four modes of maize production that are; the traditional mode in which farm equipment is used (endangered); the semi-modern mode in which animal traction is used (the most widespread); the modern mode where the motorization is used; the irrigated mode in which the crop plots undergo advanced preparation before sowing. The average yield is more and more increasing when we go from the first mode to the last, that means that the one with irrigation is the most intensive and therefore gives the best yields. The Hauts Bassins region is used as a reference for analyzing the effects of regions on the technical efficiency of farmers. The choice of this region is based on the fact that it records the largest proportion (30%) in terms of maize production. The preponderance of this Hauts Bassins region in maize production is explained by the fact that it is the main cotton-producing region, with the cotton-maize association as the dominant system (Ouédraogo, 2015). Thus, many corn farmers are "cotton farmers" at the base. Agro-climatic conditions, particularly rainfall, are also favorable for growing maize in the above-mentioned regions. A sample of 275 rained maize farmers was selected for this research.

3.1.2. Descriptive statistics of the qualitative variables

Table 1 presents the descriptive statistics of the qualitative variables. The maize farmers in this sample are mostly

men with a percentage of 84%. More than half of the farmers carry out other income-generating activities (IGAs) with a proportion of 51%. About 54% of these have already benefited from technical support from the State, an NGO or another structure. Only 30% of these maize farmers have access to credit (credit recipients). This low rate denotes the difficulties of access to financing experienced by farmers in Burkina in general and maize farmers in particular. It also appears in this sample that 52% belong to a farmers' organization (FO). Only 15% use improved seed and 32% use organic fertilizer (OF) in soil amendment. The level of education of the sample is quite low with only 35% who at least know how to read and write. Moreover, it is important to note that the semi-modern (mechanical) mode in which animal traction is used, is the most common in our sample with a proportion of about 81%.

Table 1: Descriptive statistics of the qualitative variables

Variables	Number of farmers	Percentage
Sex (1= Male)	231	84
IGA (1= yes)	140	51
Technical support (1= yes)	148	54
Access to credit (1= yes)	82	30
Type of seed (1=Improved)	41	15
Farmers'organisation membership (1=Yes)	144	52
Use of organic fertilizer (1= Yes)	87	32
literacy (1= Yes)	98	36
Type of plowing (1= mechanical)	222	81

3.1.3. Descriptive statistics quantitative variables

Table 2 presents the descriptive statistics of the quantitative variables. Maize farmers produce an average of 3952.82kg of speculation, or 3.95t of corn per farmer. There is a great disparity in production from one corn farmer to another, with the observed standard deviation of 5.38t implying the presence of both very large maize holdings and small holdings in the sample. Each corn farm uses an average of 325.47kg of fertilizers (NPK, Urea) with a large fluctuation around the average of 443.90kg. The average area planted to maize by farmer is about 2.03 ha with a standard deviation of 1.102 ha. The average age of the farmers in the sample is 44 years old. The estimated average yield of the sample is 1964.38 kg / ha or 1.96t per hectare. This yield is higher than the average yield of maize in 2012 at the national level, which was 1.5t / ha but remains low compared to the expected potential yield of 2.4t / ha (PNSR, 2012). This presages the actual existence of inefficiency in maize production.

Table 2: Descriptive statistics of the quantitative variables

Variables	Mean	Standard deviation	Minimum	Maximum
Production (kg)	3952,82	5053,93	39,76	35000
Fertilizers (kg)	325,47	443,06	10	3950
Seeds (kg)	18,96	21,94	1,25	150
labor (m/d)	7,82	5,31	3	40
area (ha)	2,03	1,10	0,022	24,99
Age (years)	44	15	17	77

3.2. Empirical modeling of the production frontier

The literature indicates that two types of models are more commonly used for estimating technical efficiency in the case of the stochastic frontier of the production function (Coelli, 1996). These models are specified by their functional forms which are of Cobb Douglas or Translog type.

The Translog form developed by Christensen et al. (1971, 1973) then by Greene (1980) does not impose a restriction on returns to scale or the possibility of substitution. It faces problems of multi-collinearity, of degree of freedom thus making the estimation of parameters difficult. The frontier of translog's stochastic production of corn farmers is as follows:

$$\ln y_i = \beta_0 + \sum_{k=1}^m \beta_k \ln x_{ki} + \frac{1}{2} \sum_{k=1}^m \sum_{l=1}^m \beta_{kl} \ln x_{ki} \ln x_{li} + v_i - u_i \quad (9)$$

Where y_i is the production in kilograms (kg) of the farmer, $i = 1, 2, \dots, N$

$k, l = \text{inputs}, 1, \dots, m$

x_{ki} : represents the index k of production factors used by the farmer i and which are:

x_{1i} : the land represented by the area planted in hectares (ha) by the farmer i

x_{2i} : the labor measured by manpower per day (number of agricultural workers) of the farmer's household

x_{3i} : the quantity of seeds in kilograms (kg) used by the farmer i

x_{4i} : the quantity of fertilizer (Urea and NPK) in kilograms (kg) used by the farmer i .

The Cobb-Douglas form is the most used in empirical studies because of its relative easiness of parameter

estimation (Coelli, 1995). Indeed, the logarithmic transformation leads to a log-linear model that facilitates economic interpretation. This form assumes a number of restrictions which are the constancy of the value of the return to scale for all observations and the value corresponding to the unit (1) of the elasticity of substitution. The Cobb-Douglas representation assumes the nullity of the β_{kl} ; that are the joint effects of the inputs. So, its logarithmic transformation is as follows:

$$\ln y_i = \beta_0 + \sum_{k=1}^m \beta_k \ln x_{ki} + v_i - u_i \quad (10)$$

Where y_i is the production in kilograms (kg) of the farmer, $i = 1, 2, \dots, N$
 $k, l =$ inputs, $1, \dots, m$

x_{ki} : represents the index of production factors k used by farmer i , listed above.

In this research, the specification of the appropriate model will be done after hypothesis testing.

3.3. Specification of the determinants of inefficiency model

According to Albouchi et al. (2007), the scale of analysis and the objective of the study induce the choice of determinants of efficiency. Based on empirical studies and field observations, fourteen (14) socio-economic and institutional variables that can influence the technical efficiency of Burkina Faso maize farmers are selected for this research. These determinants of farmer inefficiency are obtained by regressing the technical efficiency scores.

$$u_i = \delta_0 + \sum_{r=1}^s \delta_r z_{ri} + w_i \quad (11)$$

With, δ_r unknown parameters of the determinants of technical efficiency; $r = 1, 2, \dots, s$

z_{ri} : variables likely to influence the level of inefficiency of the farmers that are:

z_{1i} : the farmer's household size i (continuous variable);

z_{2i} : the age of the farmer i (continuous variable);

z_{3i} : the sex of the farmer i ; 1 if male and 0 if female

z_{4i} : the level of instruction of the farmer i (binary variable); 1 if instructed 0 if no

z_{5i} : the technical framework of the farmer i (dummy variable); 1 if yes 0 if no

z_{6i} : belonging to a peasant organization of farmer i (dummy variable); 1 if yes 0 if no

z_{7i} : access to credit by farmer i (dummy variable); 1 if yes 0 if no

z_{8i} : other income generating activities by farmer i (dummy variable); 1 if yes 0 if no

z_{9i} : type of plowing of farmer i (dummy variable); 1 if mechanical (hitched or motorized) and 0 if manual or no plowing

z_{10i} : the type of maize seed used by farmer i (dummy variable) 1 if selected 0 if local

z_{11i} : Use of organic manure by farmer i (dummy variable) 1 if yes 0 if no

z_{12i} ; z_{13i} and z_{14i} : Ownership respectively to the Boucle du Mouhoun, Cascades and Center-Ouest regions of the farmer.

In empirical studies, factors commonly identified as explanatory of technical efficiency such as age, sex, level of education, access to credit, use of fertilizers, belonging to a farmer organization, the technical supervision can favor this efficiency for some, and disfavor it for others.

The age of the farmer has an indeterminate effect on the technical efficiency of the farmers. Coelli and Battese (1995) found a positive relationship between technical efficiency and the age of the farmer, that is, the older ones are more efficient than the younger ones. This result could be understood by the fact that the older farmers have some experience in agricultural production. On the other hand, other authors support a negative relationship between these two variables because, according to them, young people are more efficient because they easily accept new farming techniques, unlike older people who are reluctant (Coelli and Fleming, 2004).

Empirical evidence of technical efficiency has revealed a strong influence of access to credit on the performance of farmers, if the funds received are actually used to purchase modern inputs (Nuama 2006, Albouchi et al., 2007). The funds allow farmers to buy the inputs needed for production (Nuama 2010), and the latter are more motivated to give the best of themselves to produce more and honor debts. However, access to credit can have a negative effect on the efficiency of farmers if funds are used for non-agricultural expenditures (Neymeck et al., 2004). In Burkina Faso, it is revealed that farmers have a great need for loans to better meet their operating expenses in the countryside: improved seeds, fertilizers, treatment products, labor, storage products, animal feed, etc..

Because of Burkina Faso's poor soils, nutrient inputs are needed in the country's agricultural production, especially cereals, including maize. As a result, the use of chemical and / or organic fertilizers has an expected positive effect on maize production. Empirically, studies have shown the positive impact of fertilizers on the production of this cereal (Sabo et al., 2010). In addition, Tchale and Sauer's (2007) analysis of Malian maize technical efficiency demonstrated the positive impact of fertilizer use on the technical efficiency of farmers with greater efficiency of integrated or mixed fertilizers users (organic and chemical).

The technical supervision covers all the activities carried out by the technical and extension services for the

benefit of farmers. These activities include training sessions on modern cropping techniques, experiments or demonstration tests, bring of agricultural inputs, participation in the agricultural project for the concerned crop, etc. Seyoum et al. (1998) showed that project beneficiaries were significantly more efficient than non-project participants with an efficiency score of 0.94. Like access to credit, the input market and local markets, technical supervision is a policy variable that has a great influence on the efficiency of farmers (Tchale and Sauer, 2007).

Membership in a farmer organization may have a positive correlation with the level of technical efficiency in that it allows, for example, easier access to credit and the grouped purchase of agricultural inputs and equipment at relatively low prices. In Burkina Faso, the State usually goes through farmer groups or associations for input distribution campaigns. This organization is strong social capitals that can help farmers reduce their level of inefficiency. However, Coelli and Fleming (2004) found that social obligations and technical efficiency are negatively correlated.

3.4. Methodology for estimating technical efficiency

Two approaches are used for estimating efficiency. These are the two-step estimate and the one-step estimate. The two-step method used by many authors (Pitt and Lee, 1981, Adégbola et al., 2006, Albouchi et al., 2007) assumes a preliminary determination of the efficiency scores and then a regression of these scores against the factors considered as determinants of efficiency. However, this method has been criticized by Battese et al. (1989) and then by Kumbhakar et al (1991) because they believe that it can omit variables that have an impact on technical efficiency and can be revealed by the one-step method. In fact, the one-step estimation by the maximum likelihood method proposed by Battese and Coelli (1995) admits that socio-economic variables can directly influence the efficiency of farmers.

In this work, the one-step method is used. Some authors such as Nuama (2006; 2010) and Onumah et al. (2010) also used this method to determine the source of inefficiency of farmers. The function of the determinants of technical inefficiency is estimated by the maximum likelihood method (ML) through Frontier software, version 4.1 implemented by Coelli, (1996). It consists of constructing the likelihood function and then determining the parameters that maximize this function. Frontier 4.1 software, iteratively outputs yields frontier elasticities, technical efficiency scores and determinants coefficients.

Formulation of hypotheses to be tested

A set of five hypothesis tests is performed to test the statistical significance of our results. However, two hypothesis tests must first be carried out: one for the choice of the functional form of the frontier and the other for the verification of the existence or not of inefficiency in the model. Then follow the other three if there is inefficiency. Thus, these five tests are formulated as follows:

The model specification test from the estimation of the translog and Cobb Douglas functional forms of the production frontier, we test the existence or not of effects of the variables of the second order. This test is written: $H_{01}: \beta_{ij} = 0$ which means that the effects of the above mentioned variables are null and therefore the Cobb-Douglas form would be adequate, the alternative hypothesis implying an adequacy of the translog form

The test of absence of inefficiency which is written $H_{02}: \gamma = \delta_0 = \delta_1 = \dots = \delta_{13} = 0$ means that there is neither inefficiency due to random exogenous shocks nor that of the farmer. In other words, H_0 not rejected implies a situation of total efficiency and the farmer would be on its optimal production frontier.

$H_{03}: \delta_0 = \delta_1 = \delta_3 = \dots = \delta_{14} = 0$. This test verifies the adequacy of the semi-normal distribution for the representation of the data.

$H_{04}: \delta_1 = \delta_3 = \dots = \delta_{14} = 0$, this hypothesis states that factors specific to maize farmers do not influence the technical inefficiency.

The test for the existence of regional effects on inefficiency; $H_{05}: \delta_{12} = \delta_{13} = \delta_{14} = 0$. This null hypothesis means that the regions have no effects on the production and the technical efficiency of the farmers.

Decision rule

According to the hypothesis to be tested, the calculated LR or the LR (one-sided error test) respectively is compared with the statistics of Chi-2 and the tabulated written by Kodde and Palm (1986) at 1% with the corresponding degree of freedom. Indeed, LR is the generalized statistic of the likelihood ratio calculated as follows.

$$LR = -2 * \{\ln [(L (H_0)) - L (H_1)]\} \quad (12)$$

Where $L (H_0)$ and $L (H_1)$ are the respective values of the likelihood function under the null hypothesis and the alternative hypothesis. LR is supposed to follow a Chi-square distribution whose number of degree of freedom is equal to the number of restrictions imposed. The LR (one-sided error test), for its part, is the statistic that has the particularity of having a mixed chi-square distribution (Coelli, 1996).

Thus, if the calculated LR value is greater than the statistic read at 1% significant level with n degree of freedom, then the null hypothesis is not accepted for hypothesis tests H_{01} , H_{03} , H_{04} and H_{05} . The null hypothesis, H_{02} , which involves γ , is not accepted when the LR (one-sided error test) is greater than the Wald statistic at 1% significant level at n degrees of freedom, always corresponding to the number of restrictions.

4. Results and discussions

4.1. Verification of hypotheses

Table 3 presents the results of the two tests prior to estimating the technical efficiency level of Burkina Faso maize farmers. It follows from the first test that the translog form is adequate for the estimation of the model, the null hypothesis (Cobb Douglas) being rejected. The second test shows the actual presence of technical inefficiency in maize production. Indeed, one obtains a LR (test one sided-error) of 113,48 higher than the Khi 2 statistic read on the table with 15 degrees of freedom, which is 29,92. This implies the non-acceptance of the null hypothesis of lack of technical inefficiency in the model. The last three tests respectively reveal the adequacy of the semi-normal distribution of the exogenous variables; the existence of farmer-specific factors as explaining the technical inefficiency in maize production and the presence of the regional effect on technical efficiency.

Table 3: Results of the hypothesis tests

HYPOTHESIS	Likelihood Ratio (LR)	Khi-2 Statistics	Decision
$H_{01}: \beta_{ij} = 0$ Cobb Douglas is adapted for the model	42,92	23,21	H_{01} is not accepted as $LR > X_{0,01}^2(10)$
$H_{02}: \gamma = \delta_0 = \delta_1 = \dots = \delta_{14} = 0$ Absence of inefficiency	106,68	31,35	H_{02} is not accepted as $LR > X_{0,01}^2(16)$ $LR > X_{0,01}^2(15)$
$H_{03}: \delta_0 = \delta_1 = \delta_2 = \dots = \delta_{14} = 0$ Inefficiency is not explained by exogenous variables	105,62	30,58	H_{03} is not accepted as $LR > X_{0,01}^2(15)$
$H_{04}: \delta_1 = \delta_2 = \dots = \delta_{14} = 0$ Inefficiency not explained by factors specific to the farmers (test of the constance of mu)	119,78	29,14	H_{04} is not accepted because $LR > X_{0,01}^2(14)$
$H_{05}: \delta_{12} = \delta_{13} = \delta_{14} = 0$ Absence of regional effects	84,04	11,34	H_{05} is not accepted because $LR > X_{0,01}^2(3)$

4.2. Analysis and interpretation of technical efficiency scores

Burkinabe maize farmers have a fairly high average technical efficiency score of 0.8390. This means that the maize farmers produce at 83% of their productive capacity. With an additional level of efficiency of 17%, farmers would reach the optimum level of maize production. In other words, by reducing technical inefficiency by 17% without the additional use of factors of production, maize farmers would be on the stochastic production frontier. This will help increase the amount of corn produced and thus improve the country's food situation. The least efficient farmer has an efficiency level of 0.29 and the most one is at the 0.96 level. The disparity between farmers in terms of efficiency is not large compared to the standard deviation of 0.14; that means the farmers in the study area have almost the same performance.

Tableau 4 : Distribution of the technical efficiency scores

Variable	Mean	Standart deviation	minimum	maximum
Technical efficiency	0,83	0,14	0,29	0,96

Distribution of technical efficiency frequencies

The frequency distribution of technical efficiency indicates that the highest proportion of maize farmers is in the technical efficiency class from 80% to 100%, where is the average of the technical efficiency of the sample that is 83%. In view of these results, we can say that the farmers of these four regions of Burkina are quite efficient in terms of agricultural productivity. The farmers closest to the stochastic production frontier whose technical efficiency varies between 80% and 96% (the maximum) have a frequency of 70.91% which is twice as high as those having a level of efficiency lower than 80%.

Tableau 5 : *Distribution of technical efficiency frequencies*

Technical efficiency index (%)	Technical efficiency	
	Number of farmers	Percentage (%)
]0;60]	31	11,27
]60;80]	50	18,18
]80;100]	195	70,91

4.3. The results of the production function

The estimate from the Frontier 4.1 software was used to determine the parameters of the production function and the technical inefficiency.

Overall, the estimated model is quite satisfactory with respect to the estimated parameters presented in Table 6. The parameter γ between zero and one means that any deviation of maize production from the frontier is due, on the one hand, to the technical inefficiency of the farmer and secondly the various random factors that are beyond the control of the operator. The gamma value of 0.54 indicates that 54% of the deviation of corn production from the border is due to the technical inefficiency of the farmers. Albouchi et al. (2007) found a γ value of 0.566 which is not very different from our result. This relatively low value of γ compared to other studies (e.g. Neymeck 0.97, Kaboré 0.88) reflects the importance of random terms v . Indeed, in the present research, 46% of the gap between observed production and potential output is explained by random exogenous factors such as measurement errors and factors beyond the control of the operator. This seems to confirm the stochastic nature of the agricultural production function.

The significant variables of the stochastic production frontier are area and fertilizer. The parameter of the area variable is positive and significant at 1%. This parameter, whose value is 1.0495, corresponds to the elasticity about the area. This implies that an increase in area of 1% leads to an increase in production of 1.0495%. This relationship relates the extensive nature of Burkinabe agriculture in general and maize in particular. Agricultural statistics also confirm this result. Studies conducted in the maize sector have shown that the growth in maize production is mainly due to the increase in areas planted for cultivation (DGPER, 2013). Indeed, there is an increasing trend in maize production between 2000 and 2012 (153%) but also areas planted for cultivation (157%). This situation, where the growth of production is conditioned by the increase in the areas planted, is not a sustainable option; the land resource being limited in the face of demographic pressure.

The fertilizer factor parameter is also positive and significant at 10%. An increase in the amount of fertilizer by 1% results in an increase in production but less than proportional of 0.062%. On the other hand, we note that the quadratic effect of the fertilizer is also positive, which shows that an exponential increase of the fertilizer will always contribute to increase the production, because there is no effect of congestion that is, a threshold at which an increase in the amount of fertilizer will lead to a decline in production. This weak effect of fertilizer (Urea and / or NPK) is explained in part by the extensive nature of maize production because intensification of production involves the renewal of soil fertilization, thus improving their productivity through the optimal use of fertilizers. The parameters of work factors and seeds are not statistically significant.

In addition, the sum of the elasticity is 1.0203; which is greater than unity. This indicates that corn production technology located in the four research regions is a function of increasing return to scale. As a result, a simultaneous 1% increase in inputs quantities relative to their averages results in a more than proportional increase of 1.0203% in maize production for farms. In the case of increasing return to scale as in this case, it is recommended that production be provided by large-sized farms.

Tableau 6 : The results of the stochastic production function

Variable dépendante : la production (lnyi) en kg

Variables	Coefficient	Standard-error
Stochastic function		
constante	0,8957**	0,0388
Lnarea	0,1028***	0,0403
Lnlabor	-0,4016	0,0428
Lnseed	-0,3129	0,0254
Lnfertilizer	0,6259*	0,0354
Lnarea2	-0,4256	0,0485
Lnlabor2	0,3564	0,1308
Lnseed2	-0,5951	0,0282
Lnfertiliser2	0,8956***	0,0327
Lnarea * Lnlabor	0,6546	0,0649
Lnarea * Lnseed	0,6337**	0,0298
Lnarea * Ln fertilizer	0,1433	0,0334
Ln labor * Lnseed	-0,6522	0,0482
Ln labor * Ln fertilizer	0,3856	0,0492
Lnseed* Ln fertilizer	-0,7925***	0,0265
The parameters of efficiency		
σ^2	0,0942***	0,0166
γ (gamma)	0,5388***	0,1168
Log likelihood	-4,1414	
LR (test of the one-sided error)	106,68	

* Significant at 10% level; ** significant at 5% level; *** significant at 1% level

4.4. Determinants of technical inefficiency of farmers

The factors determining the technical inefficiency of Burkina Faso maize farmers obtained after estimation of the stochastic production frontier are: the age of the farmer, the sex, the size of the household, the use of organic fertilizer, the use of improved variety by the farmer and belonging to the region of Boucle du Mouhoun and that of Central West.

The coefficient of the household size factor is negative and significant at 1%. Household size therefore negatively affects the technical inefficiency of the farmer. This means that large households are technically more efficient than smaller ones. This could be explained by the fact that large households will tend to give the best of them to produce more in order to ensure the consumption of maize for their members. In addition, this type of household has a larger workforce (family labor), all things being equal. This result is consistent with the work of Kaboré (2007), where he finds that extended-type households tend to be more efficient because they have the advantage of being an important source of labor.

The coefficient of the age factor is positive and significant at 5%. Age therefore acts positively on the technical inefficiency of the farmer. This means that the older the farmer is, the less efficient he is. Young people are therefore more efficient than older people. This could be explained by the fact that young people are more open to modern farming techniques that help to increase agricultural production, while the older ones are less engaged. Added to this is the fact that young people are physically vigorous for fieldwork while physical strength decreases with age, all things being equal. This result is consistent with those of Coelli and Battese (1995) and Ouédraogo (2015).

The coefficient of the gender variable is negative and significant at 10%. This implies that women taken as a reference are technically more inefficient than men. This could be understood by the fact that women have difficulty accessing land and agricultural equipment compared to men. In addition, women do not spend all their time on farms, but spend part of their time doing housework. Onumah (2010) also showed that men are technically more efficient than women.

The coefficient of the use of improved or selected maize seeds is negative and significant at 10%. The areas on which the improved seeds are applied are more productive than those which house the local varieties. Improved seeds tend to reduce technical inefficiency. This result is similar to that obtained by Chirwa (2003), in his analysis of sources of technical efficiency of maize farmers in Malawi. Adégbola et al. (2006) and Elias et al. (2014) also resulted in a reducing effect of the technical inefficiency of farmers using such type of seed. A good policy of extension and distribution of improved maize varieties is one way to increase agricultural production and improve food security in Burkina Faso.

The parameter of organic fertilizer is negative and statistically significant at 5%. A farmer who uses organic fertilizer as a soil nutrient is technically less inefficient than one who does not use organic one. In the sample, all

farmers use chemical fertilizers (Urea and / or NPK) for soil fertilization. In view of such result, it could be accepted that the use of organic fertilizer in addition to chemical fertilizer contributes to increasing the level of soil fertility and thus to improving the agricultural yields of maize. As a result, organic fertilizer tends to reduce the technical inefficiency of maize farmers. Kaboré (2007) obtained the same result for users of organic fertilizer in the Kou rice valley in Burkina Faso. The results of Tchale and Sauer (2007) are also consistent with ours.

The coefficients of the Boucle du Mouhoun and Center West regions are positive and significant at 1% and 5% respectively. This means that farmers in these two regions are more inefficient than those in the Hauts Bassins region as reference. As a reminder, the Hauts Bassins region is the largest maize producing region, so it makes sense that farmers in this region are technically more efficient than those in other regions. Apart from climatic and edaphic factors, farmers in other regions could become immersed in the cultural attitudes of farmers in the Hauts Bassins region in order to improve their technical efficiency.

The coefficients of the variables instruction, belonging to a farmer organization, technical supervision, access to credit and type of plowing are all statistically non-significant.

Tableau 7 : The parameters of the technical inefficiency

Dependante variable: inefficiency term u_i

Variables	Coefficient	Erreur-type
constante	-0,6267	0,3519
Size of the household	0,9023***	0,0031
age	0,5831**	0,0029
sex	-0,1930*	0,1111
Literacy	0,2440	0,0692
Technical supervision	-0,4491	0,0728
Farmers'organisation	-0,8593	0,0889
Credit	0,7403	0,0843
Oher activities	-0,3314	0,0811
Type of plowing	0,1304	0,0823
Organic fertilizer	-0,1702**	0,0780
Improved seed	-0,4181*	0,2172
Boucle du Mouhoun	0,8922***	0,2556
Cascades	-0,3678	0,6861
Center-West	0,4875**	0,2411

* significant at 10% level ; ** significant at 5% level ; *** significant at 1% level

5. Conclusion and recommendations

The overall objective of this study was to analyze the determinants of the technical efficiency of maize farmers in Burkina Faso. A sample of 275 farmers from four regions of Burkina based on data from the Permanent Agricultural Survey (EPA) was chosen for the study. The stochastic parametric approach was used for this analysis. The estimation of the translog function by the one-step method was performed using the Frontier 4.1 software based on the work of Coelli (1995). This estimate yielded the average level of efficiency of the farmers, the individual efficiency scores and the determinants of the technical efficiency of the country's maize farmers.

At the end of the investigations, it appears that only the area and the fertilizer affect the level of maize production with respectively positive effects. It also appears that Burkina Faso maize farmers are technically efficient at 83%. The technical inefficiency of farmers is explained by socio-economic and technological factors such as age, gender, household size, use of improved seeds, application of organic manure, membership of the Boucle du Mouhoun and Central West regions.

Older farmers are technically less efficient than younger ones, women are also less efficient than men, farmers in Boucle du Mouhoun and Center-Ouest regions are less efficient than those in Hauts Bassins which is the region of reference. However, the technical efficiency has been improved through the use of improved maize seeds and the application of organic manure in soil amendment

In view of these results, the following agricultural policies can be proposed to allow farmers to get closer to their potential level of production without the additional use of factors of production: attracting young people to maize production; accompany women in the production of maize by facilitating access to land, equipment and especially improved varieties and training on the optimal use of organic fertilizer; invest more in agricultural research and make improved seeds available to all farmers; train farmers on organic manure production techniques and its optimal use for sustainable cereal production.

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