Technical Efficiency of Small-Scale Maize Producers in Benin

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Research Paper 418

Bringing Rigour and Evidence to Economic Policy Making in Africa

AFRICAN ECONOMIC RESEARCH CONSORTIUM
CONSORTIUM POUR LA RECHERCHE ÉCONOMIQUE EN AFRIQUE

Technical Efficiency of Small-Scale Maize Producers in Benin

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AERC Research Paper 418
African Economic Research Consortium, Nairobi
March 2021

THIS RESEARCH STUDY was supported by a grant from the African Economic Research Consortium. The findings, opinions and recommendations are those of the author, however, and do not necessarily reflect the views of the Consortium, its individual members or the AERC Secretariat.

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

ISBN 978-9966-61-116-1

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Abstract

Given the importance of maize as a food crop in Benin and the objectives of the country regarding this product in terms of food security and exports, a study on maize production is of primary importance. This study aims to analyze the way small-scale maize producers allocate their production factors and to identify the elements that are inherent to an efficient maize farming operation. The Cobb-Douglas Stochastic Frontier approach is used to estimate the level of technical efficiency of maize growers. The mean score in technical efficiency in maize production in the sample used is estimated at 65.40%, with a minimum of 20.47% and a maximum of 93.46%. The results indicate that the sex of the farmer, use of enhanced seeds, selling price of maize, percentage share of non-agricultural income, contact with an NGO, access to finance, and production zone play a positive and significant role in the attainment of a production frontier. The results lead us to recommend that the government reduces its expenditure on agricultural extension services and instead emphasize the policy on distribution of improved seeds. Equally, constraints in the capital and labour markets contribute to the low efficiency of agricultural households.

JEL classification codes D24, O13, Q12.

Key Words: Technical efficiency, maize, Benin, Stochastic frontier

1.0 Introduction

1.1 Overview

Benin is heavily dependent on its agricultural sector, which contributes to 32.4% of the Gross Domestic Product (GDP) and 80% of the official export revenues (World Bank, 2010). However, the sector is lagging in terms of modernization and diversification. Indeed, Benin's agricultural sector is dominated by the cotton sector, which represents between 25.0% and 40.0% of total exports and 34.7% of official export revenue (World Bank, 2010). These strong indicators in the sector are, however, undermined by problems of organization, climatic variations and the continued use of outdated production tools. The crisis in the cotton sector has become quite evident since the campaign of 1999-2000, and has exposed the fragility of Benin's economy, as it relies on the export of a single commodity (PPAB[1], 2001). This fragility has been exacerbated by the various food and economic crises experienced by developing countries and especially the food crisis of 2006-2008.

Therefore, agricultural diversification and food production have become a priority for development actors in the agricultural sector. Benin is now promoting other promising sectors, such as that of maize production. Indeed, maize is currently the leading food product in Benin, way ahead of rice and sorghum (EMICoV[2], 2011). This demonstrates the importance of this particular crop in terms of food security. The government has seen it as an important component in its Strategy for Growth and Poverty Reduction. In the policy document, the government clearly established an objective to increase maize production from 841,000 tonnes produced in 2005 to 1,100,000 tonnes, to attain a food balance sheet of at least 250,000 tonnes by the year 2011. Maize production is also an important aspect in the revitalization of the agricultural sector, whereby it is envisaged that by 2015, Benin will produce an average of 1,900,000 tonnes of maize per year, and the country will have sustainable engagements in terms of trade exchanges in the countries of the sub-region and further afield (SCRP[3], 2007).

Programmes for an increase in productivity and agricultural production have been put in place through distribution of fertilizer, making seeds available to farmers,

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[1] Programme for the promotion of professionalism in the agricultural sector of Benin

[2] An Integrated Modular Survey on the Living Conditions of Households

[3] Strategy for Growth and Poverty Reduction

and allocating land to farmers. However, these diverse policies have had a limited reach because by the end of the period 2011-2015, Benin's objective in regard to an increase in maize production had not been attained since maize production was at 1,438,918 kilogrammes in 2015 (ONASA[4], 2016) and most of the economic potential of the sector had not yet been exploited. Indeed, just like production, the yields of maize have experienced an increase from 600 kg/ha on average in 1970 to 1,400 kg/ha in 2009 (ONS[5], 2010), then 1,103 kg/ha in 2010; 1,422 kg/ha in 2011; 1,251 kg/ha in 2012; and 1,346 kg/ha in 2013 (FAOSTAT, 2015). The yield from maize plantations is still low compared to other regions in the world such as Burkina Faso where the maize yield was 1,434 kg/ha in 2010; 1,536 kg/ha in 2011; 1,839 kg/ha in 2012 then 1,799 kg/ha in 2013 (FAOSTAT, 2015) because farmers have poor control over the production costs. Despite this improvement in maize yields, it must be noted that this yield has been seesawing, which leads to fluctuations in the food balance sheet that are sometimes in worrying proportions. This leads to threats both in terms of food security and income of farmers, and by extension to higher poverty levels. To reduce poverty in Benin, the income of workers actively involved in agriculture has to increase by 70% (BAD et al. 2012). This is because any increase in agricultural productivity by 1% in Africa reduces poverty by 0.6%, and an increase in production by 1% leads to a decrease in the number of people living on less than one dollar a day by 6 million (Thirtle et al., 2003).

These mixed results in regard to the diverse programmes undertaken could be explained through the fact that the programmes are implemented in a general manner throughout the country without taking into account the specificities linked to each region in terms of constraints, and the conditions of production faced by the producers. Equally, production factors that are linked to sub-optimal agricultural practices could also partly contribute to the situation. Furthermore, maize is still cultivated under conditions linked to constant soil degradation, characterized by the persistence of traditional practices and lack of knowledge on the use of improved processing equipment, coupled with low education levels of actors in the sector (ONS, 2010). This situation translates into a weak valorization of the economic potential of this sector given the demand regarding poultry farming, brewing, and the production of infant cereals, which remain unsatisfied in relation to neighbouring countries.

Moreover, several countries on the continent, including Benin, are importers of food products, which include maize, at an import level of 1,058.3 tonnes and 1,272.55 tonnes in 2013 and 2014, respectively (INSAE, 2016). Thus, focusing on efficiency in the production of maize would have the potential of addressing questions not only about food security but also about the unreasonably high volume of importation of food products. It is, therefore, important to know whether the various production units of maize in Benin are efficient in their use of available resources. Indeed, an increase in the production volume through an increase in the productive resources

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[4] National Bureau of Food Security

[5] National Farmer Income Support Bureau

(sown area in this case) is not a sustainable option. An increase in production does not necessarily suggest an overall increase in productive resources but could also arise from changes in the way existing resources are managed. This study will allow for the identification of elements that could improve production given the idiosyncrasies of each region, recommendations that will target farmers in the region, and the authorities responsible for implementation of agricultural policies.

1.2 Research Objectives and Hypotheses

This study proposes an analysis of the technical efficiency of small-scale maize farmers in Benin. More specifically, the study aims to: (1) Determine the level of technical efficiency of small-scale maize farmers; (2) Break down the levels of technical efficiency of maize farmers according to agro-ecological zones and the variety of seeds used; and (3) Identify socio-economic and technical variables that characterize efficient farms. The paper aims to test the following hypotheses: (i) Maize producers could increase their level of efficiency by changing their combinations of production factors; (ii) The degree of efficiency differs according to the agro-ecological zone and according to the seeds used; (iii) socio-economic and technical variables such as access to finance, age, education, contact with extension officers, use of enhanced seeds, the selling price of maize and climate determine the efficiency of producers.

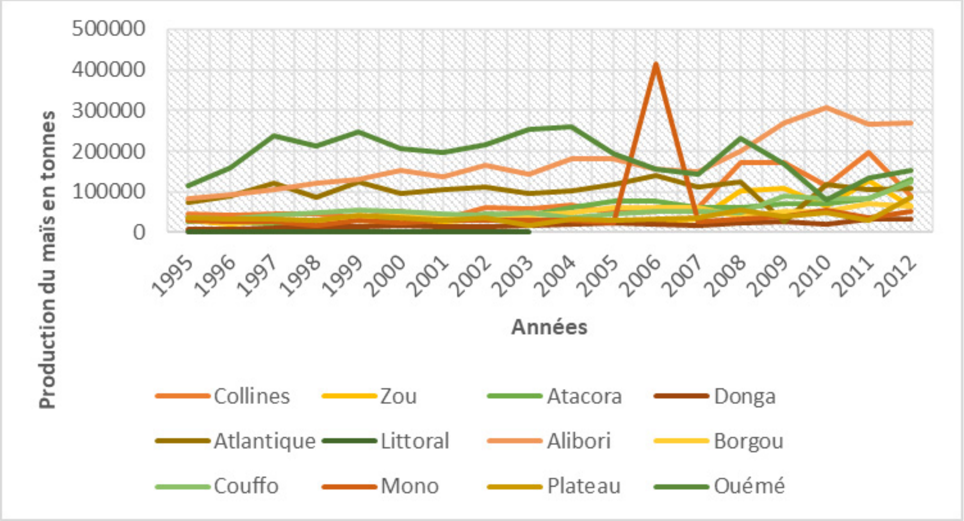
The rest of the paper is divided into the following sections. The rest of this section presents statistics on maize production in Benin. Literature on the subject is presented in section 2. The methodology and the data used are the focus of section 3. The analysis of results is given in section 4. Finally, the conclusions and policy implications are presented in section 5.

1.3 Statistics on Maize Production in Benin

In this section, we present data on the evolution of maize production in Benin per region. The illustration in Figure 1 allows us to observe that maize production at the regional level, just like production at the national level, has been seesawing over the period 1995 to 2012. Figure 1 shows that the regions which contribute by the highest mean to the national production of maize in Benin are Ouême, Alibori, and Atlantic, with an average contribution of 55.91% over the period 1995-2012. Their highest contribution was noted in 1997 with a percentage of 67.22% and their lowest contribution was in 2006 with a percentage of 37.82%. These performances can be justified through the fact that these regions are in a zone where the climate is Sudano-Guinean with two rainy seasons and with very fertile alluvial soil. Furthermore, the crop systems in these regions are dominated by maize.

The regions that contribute the least to national production of maize are Littoral and Donga with an average contribution of 2.13% over the period 1995-2012. The highest contribution from these regions was at 2.97% in 2011 and their lowest contribution was 1.37% in 1997. This could be partly justified through the fact that Cotonou is part of the Littoral region and, therefore, land for agricultural use is practically inexistent, especially for maize growing. Furthermore, land in the region is not very fertile. In the Donga region, climate is of the Sudano type with a single rainy season and iron-rich tropical soils that are of variable fertility. The crop system in this region is dominated by sorghum and yams.

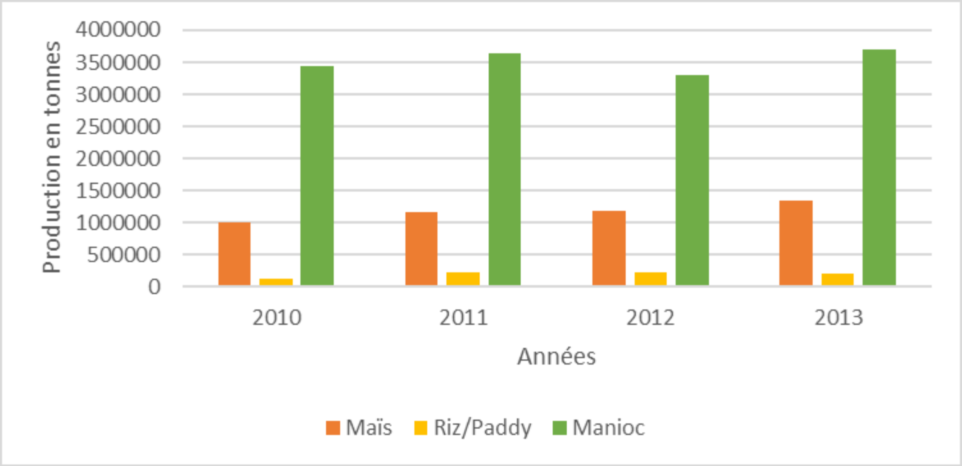
Figure 1: Evolution of maize production (in tonnes) per region from 1995 to 2012



Source: Plotted by the author using data derived from ONASA (2016)

An analysis of the comparative evolution of maize production, rice/paddy and cassava in Benin between 2010 and 2013 (Figure 2) shows that production of maize experienced a regular increase over the period compared to other crops whose production experienced a seesaw evolution over the same period. This performance is due to the steps taken by the government through acquisition and implementation of agricultural inputs of sufficient quantities in good time, and through the hiring of new extension agents and the setting up of institutions at the grassroots level to improve the productivity of this crop, which is still the leading food crop in Benin. Nevertheless, the average growth rate of maize production between 2010 and 2013 is 10.15% against 23.32% and 2.79% for rice/paddy and cassava, respectively.

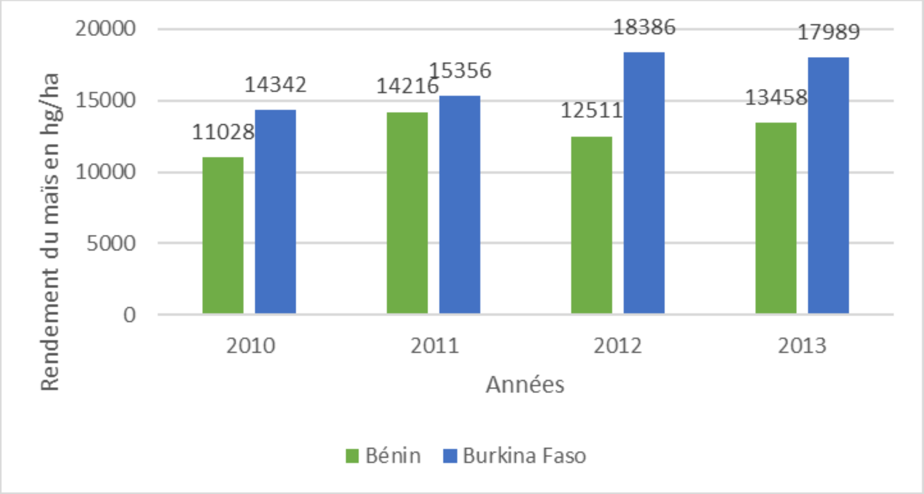
Figure 2: Comparative evolution of maize, rice paddy and cassava production in Benin



Source: Plotted by the author using data from FAOSTAT (2015)

By observing the evolution of maize yields in Benin compared to those of Burkina Faso between 2010 and 2013 (Figure 3), we note that maize yields in Burkina Faso experience a positive evolution over the period whereas those of Benin are seesawing, just like was the case in production. However, the average growth rate of maize yields in the two countries is practically similar over the period, with 8.16% for Benin and 8.21% for Burkina Faso. These trends are unacceptable in so far as the climatic and geographic conditions are more favourable towards production in Benin than in Burkina Faso. However, they could be explained through the fact that Burkina Faso has put in place strategies that allow farmers to overcome climatic and geographic constraints (for example the implementation of irrigation systems) unlike Benin. This allows growers to have good control over their production system and to have full-time production.

Figure 3: Comparative evolution of maize yields in Benin and in Burkina Faso



Source: Plotted by the author using data from FAOSTAT (2015)

2.0 Literature Review

Studies dealing with the efficiency of agricultural farms have a long history and are based on methods that are rapidly developing and on advances in Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) methods. In this section, we present the theoretical framework on the notion of efficiency and empirical studies on the efficiency of agricultural farms.

2.1 Theoretical Framework on the Concept of Efficiency

Efficiency covers vast and sometimes varied elements. It integrates a corpus of more precise notions on production, of cost, or of price, profit, etc. The frontier reflects the maximum quantity of output that could be attained for a given level of inputs (production frontier); the minimum production cost of the output for a given level of prices of inputs (cost frontier); or the maximum profit that could be attained for a given level of prices of outputs and inputs (profit frontier). In all these cases, technology and fixed factors are also considered. Leibenstein (1966) through the concept of "X-efficiency" considers the optimal non-systematic behaviour of farmers. In terms of comparative analysis, the frontier captures the best practices.

Economic literature identifies two types of efficiency, namely economic efficiency and scale efficiency. Economic efficiency comprises of technical efficiency and allocative efficiency. According to Koopmans (1951), a producer is technically efficient if an increase of whichever output necessitates the diminution of at least one other output or an increase by at least one input, and if a decrease in whichever input necessitates an increase of at least one other input or the diminution of at least one output. In other words, a technically efficient firm has to situate itself on the frontier of its entire production system.

Farrell (1957) defines efficiency in a more specific manner by disassociating what is technical from that which is as a result of poor choices regarding the price of inputs. Technical efficiency thus measures the manner through which a firm combines its production factors when their proportions of use are provided. There is technical efficiency when one can obtain the same level of outputs using less inputs. Cost efficiency measures the way a firm fixes the proportions of various inputs used for a productive combination based on their respective costs. This measurement gives a feel of the way firms allocate their productive resources regarding their production objectives. Thus, the term "allocative efficiency" is often used in place of the term cost efficiency, which was used by Farrell (1957). In other words, allocative efficiency could be defined as the capacity of producers to choose inputs in optimal proportions.

A breakdown of economic efficiency into a technical component and an allocative component was proposed by Farrell (1957) through an illustrative example. Technical inefficiency corresponds to the use of a quantity of inputs that is higher than necessary for a given level of outputs. It is estimated through the deviation frontier established by the highest performing firms among those sampled. Allocative inefficiency measures the use of inputs in proportions that do not correspond to the optimal output as is established through the relative prices of inputs.

Obtaining technical and allocative efficiency simultaneously is a necessary and sufficient condition for economic efficiency. It is possible for a firm to be technically or allocatively efficient without being so economically. Economic efficiency, therefore, comes about as a result of technical efficiency combined with allocative efficiency, as exclusive and comprehensive components of economic efficiency (Adegbola et al., 2008). Scale efficiency, on the other hand, determines in what measure a production unit functions with increasing or decreasing returns to scale, which allows for a definition of the optimal size of a production unit.

Economic theory offers several approaches for the calculation of efficiency. Two techniques are most frequently used for frontier estimation. These are the Data Envelopment Analysis (DEA) and the Stochastic Frontier Analysis (SFA) methods.

Stochastic Frontier Analysis (SFA) is a method of economic modelling. It uses as its point of departure Stochastic Frontier methods that were simultaneously introduced by Aigner et al. (1977) and Meeusen and Van den Broeck (1977). The main differences between the DEA and SFA approaches are to be found specifically in the two characteristics of DEA that have been described above. Whereas the DEA method is deterministic and non-parametric, the SFA method assumes a Stochastic relationship between inputs and outputs, and it is a parametric approach. The main advantage of the SFA method is that it does not attribute all deviations related to the frontier specifically to efficiency. The distance between the input/output combinations observed can be partly attributed to inefficiency and partly to data error, resulting in an imprecise measurement of inputs and/or outputs. This characteristic exists at the expense of the necessity to impose a functional form to allow for the estimation parameters of the model. According to Coelli et al. (1998), the SFA method is the most appropriate for agricultural use, particularly in developing countries, given that agriculture strongly relies on random phenomena (climate). A major problem with SFA when applied to the agricultural data of developing countries is that it does not allow for zero inputs. This approach will be used in the study because it is often preferred in the analysis of efficiency in agriculture, because random non-observed factors could act on agricultural production, and the data at the level of agricultural holdings generally contains a considerable amount of errors (Nasim et al., 2014). Moreover, our data will facilitate our analysis.

2.2 Empirical Studies on the Effectiveness of Agricultural Holdings

Very few studies on agricultural efficiency use the DEA method (for example Dhungana et al., 2004; Djimasra, 2010; Ogundari, 2013). Most seminal texts in the area apply the SFA method. Studies by Alene and Hassan (2006), Dinar et al. (2007), de Magalhães et al. (2011), Chen et al. (2009), Idiong (2007), Abdulai and Tietje (2007), Liu and Myers (2009) and Nasim et al. (2014) use the same method for agriculture.

For example, by using the Stochastic Frontier function and a Cobb-Douglas production function in a study on the technical efficiency of specific inputs for each district of India, Venkataramani et al. (2006) found that an improvement in health is associated with a significant improvement in technical efficiency. Similar results were obtained by Loureiro (2009) who found that differences in the health status of farm labourers explain the variance in production efficiency in Norway.

Furthermore, in a comparative study of poor and non-poor agricultural holdings, Ahmad (2003) demonstrated that elasticity of farm production is significantly higher in rich farms compared to farms belonging to poorer farmers. In addition to this, the average cost of the existence of technical inefficiencies was close to 43% in terms of production losses, with wide variations between the farms ranging from 17% to 62%. He also concluded that the less performing groups did not uniquely function below the frontier but were also to be found at the lower part of the production frontier. Consequently, an increase in access to inputs would likely increase productivity and reduce poverty. Moreover, Costa et al. (2013) studied the relationship between agricultural productivity and food security in households of the metropolitan areas of Brazil, considering other individual factors. They observed that productivity gains were associated with a higher level of household food security and, in a very small way, also attributable to the influences of characteristics such as education and income.

With a view to identifying the determinants of technical efficiency, Koirala et al. (2013) used the Cobb-Douglas function in studying rice farmers in the Philippines. The results demonstrated that fuel, fertilizer, land rent, planting season and size of the farmland were factors affecting productivity and the technical efficiency of rice production. They found an average score of technical efficiency of 0.54. A similar study was undertaken by Mohammed and Saghaian (2014) on rice production in South Korea. Their study demonstrates that it is possible to increase production efficiency and technical efficiency, and that site effect has a significant impact on production yield.

In the case of Benin, Adégbola et al. (2008) examined levels of technical, allocative and economic efficiency of rice production systems, which are located in the competitive areas of Centre and in the North East, using a Stochastic production function. The findings of the study show that rice growers were on the whole inefficient; 62% of the change in rice yield was especially due to technical inefficiency. However, the distribution of the efficiency indexes demonstrated that in regard to technical efficiency, 77% of rice growers had an efficiency index that was above 50%, 97% of the rice farmers in terms of allocative efficiency and 50% for economic efficiency. The most efficient rice farmers were those who used herbicides, draught power and improved seed varieties on their small parcels of land. There was also, among these different classes of producers, production plants that were technically and economically inefficient, and the bigger farms were not more efficient than smaller ones.

The studies that we have examined above suggest that technical efficiency varies according to household characteristics, and the impact of these characteristics varies according to the various regions. In addition to this, they use the Tobit model in the second step to identify the determinants of inefficiency. This is econometrically biased because the Tobit model assumes a double censure on the level of efficiency scores, which is not the case because the scores are nothing but proportions that are naturally comprised between 0 and 1 (Baum, 2008; Ramalho et al., 2010)[6]. Thus, for our study, the Fractional Regression Model developed by Papke and Wooldridge (1996) will be used to estimate the second step of the SFA method.

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[6] We will tackle this aspect in a more detailed manner while discussing methodology.

3.0 Methodology and Data

In this section, we first of all tackle the agricultural household theoretical model, then follow that up with measures of production efficiency.

3.1 Agricultural Household Model

The model that we present in this sub-section is drawn from studies undertaken by Singh et al. (1986) and Chavas et al. (2005). In the presence of rigidities in the labour market and/or common technology in agricultural and non-agricultural activities, the appropriate level of analysis is the household. A measure of productive efficiency at the farm level (rather than at the household level) would be invalid in the context presented below.

Let us consider an agricultural household m m with family members making decisions on production, consumption and the allocation of labour during a specific period. Let $F = (F_1, \ldots, F_m)$ the quantity of family labour used in agricultural work, whereby F_i is the amount of time used by the member.

The ho The household uses family labour $\boldsymbol{F}$, salaried workers, i^{th} and other i$i = 1, \ldots, m$ncluding the land) to produce a vector of agricultural H production y. The m family members can also spend their time on non-agricultural activities. Being $L = (L_1, \ldots, L_m)$, the quantity of labour used by the m family members for non-agricultural activities, generating non-agricultural revenue N. The technology which the family is faced with is represented by the feasible set X whereby $(x, F, H, L, y, N) \in X$ signifies that the inputs (x, F, H, L) could produce outputs (Y, N). The productivity of agricultural and non-agricultural labour could vary between family members. Let T be the total amount of time available for each family member over the period under study. The m family members could thus allocate their time between hobbies $l = (l_1, \ldots, l_m)$, farming activities, and non-agricultural activities $F = (F_1, \ldots, F_m)$ submitted to the satisfaction of time constraints:

$$l_i + F_i + L_i = T_{,}\ i = 1, \ldots, m\ i = 1, \ldots, m \tag{1}$$

The agricultural household consumes goods z purchased at market price $\boldsymbol{q}$.Let us assume for now that the household is faced with competitive markets[7]. Let us

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[7] Competitive markets are necessary to establish the seperability results obtained below, which would not be obtained In the presence of market imperfections that constrain access to markets.

designate by $(\boldsymbol{p},\ \boldsymbol{r},\ w)$, the market price, whereby $\boldsymbol{p}$ is the price vector of agricultural products $\boldsymbol{y}$,$\boldsymbol{r}$ is the price vector of other inputs x and w is the wage rate of the salaried workers H.Consumption decisions are subjected to the following budget constraint:

$$\boldsymbol{q}'\boldsymbol{z} \leq \boldsymbol{p}'\boldsymbol{y} - \boldsymbol{r}'x - wH + N\boldsymbol{q}'\boldsymbol{z} \leq \boldsymbol{p}'\boldsymbol{y} - \boldsymbol{r}'x - wH + N \tag{2}$$

Equation (2) indicates the expenditure on consumption $(\boldsymbol{q}'\boldsymbol{z})$, which cannot surpass agricultural income $(p'y)$, less the cost of agricultural production $(\boldsymbol{r}'x\ +\ wH)$, $(\boldsymbol{r}'x\ +\ wH)$, plus non-agricultural income (N).

Decisions on production, consumption and labour are undertaken by household members. Let us consider the case where such decisions are taken by the members of a household based on cooperative negotiations. Let us assume that the preferences of the household could be represented by a utility function for the household $U\ (\boldsymbol{z},\ \boldsymbol{l})$ defined by $(\boldsymbol{z},\ \boldsymbol{l})\ \geq\ 0$, whereby $U\ (\boldsymbol{z},\ \boldsymbol{l})$ is a "function of social utility" aggregating the preferences of members of the household and reflecting their power of negotiation. We will assume that the utility function $U\ (\boldsymbol{z},\ \boldsymbol{l})$ is non-fulfilled and quasi-concave in $(\boldsymbol{z},\ \boldsymbol{l})$. Under the cooperative negotiations, the household decisions are arrived at based on the following optimization problem:

The utility maximization problem (3) represents the economic rationality of the

$$\max_{x,\boldsymbol{F},H,\boldsymbol{L},\boldsymbol{y},N,\boldsymbol{z},\boldsymbol{l}} \{U(\boldsymbol{z},\boldsymbol{l})\text{: équations } (1) et\ (2), (x,\ \boldsymbol{F},\ H,\ \boldsymbol{L},\ \boldsymbol{y},\ N)\ \in\ X\} \tag{3}$$

household, and

$$x^{+}(\boldsymbol{q},\boldsymbol{p},\boldsymbol{r},w), \boldsymbol{F}^{+}(\boldsymbol{q},\boldsymbol{p},\boldsymbol{r},w), H^{+}(\boldsymbol{q},\boldsymbol{p},\boldsymbol{r},w), \boldsymbol{L}^{+}(\boldsymbol{q},\boldsymbol{p},\boldsymbol{r},w), \boldsymbol{y}^{+}(\boldsymbol{q},\boldsymbol{p},\boldsymbol{r},w), N^{+}(\boldsymbol{q},\boldsymbol{p},\boldsymbol{r},w),$$

designates the supply and demand functions resulting from the behaviour of utility maximization by the household.

In relation to the hypothesis of non-fulfilment of the utility function $U\ (\boldsymbol{z},\ \boldsymbol{l})$,$U\ (\boldsymbol{z},\ \boldsymbol{l})$, budgetary constraint (2) is necessarily linked to the optimization problem (3) and can be broken down into two steps. First of all, one chooses $(x,\ \boldsymbol{F},\ H,\ \boldsymbol{L},\ \boldsymbol{y},\ N)$ $(x,\ \boldsymbol{F},\ H,\ \boldsymbol{L},\ \boldsymbol{y},\ N)$.

The first step of optimization takes into account that $(x,\ \boldsymbol{F},\ H,\ \boldsymbol{L},\ \boldsymbol{y},\ N)$ can be written as:

$$\pi(\boldsymbol{p},\boldsymbol{r},w,\boldsymbol{T}-\boldsymbol{l}) = \max_{x,\boldsymbol{F},H,\boldsymbol{L},\boldsymbol{y},N} \left\{\boldsymbol{p}'\boldsymbol{y} - \boldsymbol{r}'x - wH + N :\ \begin{matrix}(x,\ \boldsymbol{F},\ H,\ \boldsymbol{L},\ \boldsymbol{y},\ N)\ \in\ X;\ F_i + L_i = T - l_i,\\ i = 1, \dots, m\end{matrix}\right\}$$

$$(4a)$$

Whereby $(\boldsymbol{T}\ -\ \boldsymbol{l})\ \equiv\ (T\ -\ l_1,\ \dots,\ T\ -\ l_m)$ is the time spent by members of the m family on agricultural and non-agricultural activities. The equation (4a) established profit maximization by taking into account the household choice $(x,\ \boldsymbol{F},\ H, \boldsymbol{L},\ \boldsymbol{y},\ N)$ of the household with $\pi(\boldsymbol{p},\boldsymbol{r},w,\boldsymbol{T}-\boldsymbol{l})$ being the function of indirect conditional profit to $(\boldsymbol{T}\ -\ \boldsymbol{l})(\boldsymbol{T}\ -\ \boldsymbol{l})$.. However, the empirical analysis presented below only needs a good working of the output market to be valid. Therefore, our approach and our research will remain viable even with the presence of imperfections in the market factors. .

To observe that maximization of household utility (3) involves the maximization of profit (4a), it is important to note that, for $(T - l)$ $(T - l)$given, an error in the maximization of profit would reduce household income, which would limit expenditure on consumption (equation (2). In relation to the hypothesis of non-fulfilment, this would leave the household worse off. Therefore, an error in the maximization of profit would be incompatible with the maximization of household utility, whereby the solution to$x^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l),\mathbf{F}^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l),H^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l),\mathbf{L}^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l)$ $x^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l),\mathbf{F}^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l),H^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l),\mathbf{L}^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l)$thequantitiesof inputs and of labour that maximize profit, and $\mathbf{y}^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l)\ et\ N^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l)$ $\mathbf{y}^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l)\ et\ N^*(\mathbf{p},\mathbf{r},w,\mathbf{T}-l)$ the production that maximizes profit. We also have to note that choices on the profit function $\pi(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - l\, \pi(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - l$) and on the related production function do not depend on $\mathbf{z}$ $\mathbf{z}$ because those variables only appear in the utility function (in other words, they are not technological functions), which implies that the production decisions are "separable" from consumption decisions. However, the profit function $\pi(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - l)\pi(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - l)$ and the production choices depend on the amount of time allocated to labour $(\mathbf{T} - l)$ $(\mathbf{T} - l)$. The nature of this relationship is described below.

Given that utility maximization (3) entails maximization of profit (4a) as the first step in optimization, the choices of the second stage, which take$(\mathbf{z}, l)$ into account become:

$$\max\{U(\mathbf{z}, l): q'z \leq \pi(p, r, w, \mathrm{T} - l)\} \max_{\mathbf{z},l}\{U(\mathbf{z}, l): q'z \leq \pi(p, r, w, \mathrm{T} - l)\}$$
$(4b)(4b)$

Equation (4b) is a standard problem of utility maximization under household budgetary constraints. A combination of the two steps (4a) and (4b) is entirely compatible with the maximization of utility (3). Below, we are going to focus on profit maximization (4a) as the appropriate framework within which to analyze productivity efficiency at the household level. With the presence of market imperfections and/or poor management skills, it is possible that households may not respond to economic incentives. Therefore, an economic analysis based on (4a) could give us an overview of the nature and the causes of economic inefficiency.

It should be noted that equation (4a) comprises agricultural and non-agricultural activities, both in terms of labour allocation ($(F\ et\ L)$) and of income $(p'\ y$ and $N)$ at the household level. It involves general technology X, allowing for joint household choices on agricultural and non-agricultural activities, which allows for conjoined decisions by the household on agricultural and non-agricultural activities. For example, the know-how acquired from the non-agricultural activity that improves agricultural management and non-agricultural income reduces the harmful effects of imperfections in the financial markets on agricultural decisions.

In the studies cited above, the economic analysis of efficiency in agricultural production is mostly done at the farm level (and not at the household level). In which conditions is an approach that focuses on the farm appropriate? As we argue below, an analysis at the farm level could be appropriate if the technologies of agricultural and non-agricultural activities are conjoined. In the case of non-conjoined technologies, agricultural technology is represented by $(x, \boldsymbol{F}, H;\ \boldsymbol{y}) \in X_f$, whereas non-agricultural is $(\boldsymbol{L}, N) \in X_n$. Then, general household technology is $X = \{(x, \boldsymbol{F}, H, \boldsymbol{L}, \boldsymbol{y}, N) : (x, \boldsymbol{F}, H, \boldsymbol{y}) \in X_f;\ (\boldsymbol{L}, N) \in X_n\}$. This simply indicates that, with the exception of time constraints (1) household technology X_f *et* X_n could be wholly expressed in terms of distinct technology X.

Whereby the production frontier $N = g\,(L)$ represents the limit of non-agricultural production or $X_n = \{(\boldsymbol{L}, N) \colon N \leq g\,(L),\ L \geq 0\}$. Under non-conjoined technology,

$$\pi(\boldsymbol{p}, \boldsymbol{r}, w, \boldsymbol{T} - \boldsymbol{l}) = \max_{x,F,H,y} \{p'y - r'x - wH + g(T - l - F) \colon (x, F, H, y) \in X_f\} \qquad (4a')$$

hence $(\boldsymbol{T} - \boldsymbol{l} - \boldsymbol{F}) \equiv (T - l_1 - F_1, \ldots, T - l_m - F_m) = (L_1, \ldots, L_m)$ from the time constraint (1).Next, we consider the case whereby $g\,(L)$ is linear in L whereby $g(L) = \sum_{i=1}^{m} w_{L_i} L_i$ and w_{L_i} could be interpreted as the wage rate received by the i^{th} member of the family from a non-agricultural activity $i = 1, \ldots, m$. In this case, assuming that $W_L = (w_{L_1}, \ldots, w_{L_m})$, equation $(4a')$ entails the following optimization problem at the farm level (rather than at the household level):

$$\pi(p, r, w, W_L) = \max_{x,F,H,y} \{p'y - r'x - wH - \textstyle\sum_{i=1}^{m} w_{L_i} F_i \colon (x, F, H, y) \in X_f\} \qquad (4a'')$$

Where $\pi(p,\ r,\ w,\ W_L, T - l) = \pi_f(p, r, w, W_L) + \sum_{i=1}^{m} w_{L_i}[T - l_i]$ and $(\sum_{i=1}^{m} w_{L_i} T)$ is the "total income", which measures the total value of household time. Equation $(4a'')$ shows that the salary rate w_{L_i} which measures the opportunity cost of agricultural labour L_i for each member of the family, $i = 1, \ldots, m$ when the wage rate is isolated using $w = w_{L_1} = \cdots = w_{L_m}$, we obtain the standard model for an agricultural household (Singh et al.,1986). Equation ($4a''$) gives the inputs, agricultural labour and agricultural production which maximizes on profit, but at the level of the farm rather than that of the household. As demonstrated by Singh et al. (1986), these decisions at the farm level are separable both in terms of consumption and in engaging in non-agricultural activities. As shown in equation (4a), optimal production choices of $x,\ \boldsymbol{F},\ H,$ and $\boldsymbol{y}$ in equation $(4a'')$ do not depend on consumption choices $\boldsymbol{z}$. However, contrary to equations $(4a)$ or $(4a')$, they no longer depend upon $(\boldsymbol{T} - \boldsymbol{l})$.This constitutes a significant difference between equations $(4a')$ and $(4a'')$.

Equation $(4a'')$ could constitute the basis of an analysis of efficiency at farm level, as is currently used by the aforementioned researchers. However, we have just demonstrated how two key hypotheses are necessary to render equation $(4a')$ compatible with equation $(4a'')$: (a) The agricultural and non-agricultural technology have to be non-correlated; and (b) The wage rate W_L has to measure the opportunity cost of using family farm hands $\boldsymbol{L}$. This signifies that the two hypotheses should be proven to justify the standard approach for the analysis of agricultural efficiency at farm level. Indeed, in tandem with joint technology, neither equation $(4a')$ nor equation $(4a'')$ agrees with them. Therefore, analyses of technical, allocative and/or scale efficiency must be conducted at the household level based on equation $(4a)$ to capture the conjoined relationship between agricultural and non-agricultural activities. In the absence of non-correlated technology, the application of equation $(4a')$ means that the analysis of technical efficiency can be undertaken at the farm level. However, this is not always enough to obtain equation $(4a'')$. Effectively, arriving at equation $(4a')$ from equation $(4a'')$ requires that the opportunity cost of family agricultural labour $\boldsymbol{L}$ be the same as the wage rate W_L. If this hypothesis is not verified, then the allocative efficiency (including the time allocation) should not be done on the basis of equation $(4a'')$: It should be based on equation $(4a')$ under non-conjoined technology, or equation $(4a')$ under conjoined technology.

This demonstrates that if the opportunity cost of family labour is not at the wage rate W_L (for example due to rigidity in the labour market) and if agricultural and non-agricultural activities are part of conjoined technology, the measures produced in equation $(4a')$ would be invalid. In this context, equation $(4a'')$ would be the privileged approach. Furthermore, equation $(4a'')$ provides an appropriate framework analysis of efficiency of the two agricultural and non-agricultural activities. The empirical implementation of equation $(4a'')$ is discussed below.

3.2 Measures of Productive Efficiency

To estimate productive efficiency, a production function is used so that efficiency may be analyzed[8]. A non-optimal use of production factors that may be favoured by Benin farmers (huge constraints on the labour and finance markets) suggests technical inefficiency well known as X-inefficiency (Leibenstein, 1966). In considering that farmer i uses several inputs X to produce a single or several outputs Y, a production function could be written to represent a particular technology: $Y_i = f(x_i)$ or $f(x_i)$ as a production frontier. At the frontier, the producer produces a maximal output from a given group of inputs or uses a minimum amount of inputs to produce a given level of outputs. In macroeconomic theory, an absence of inefficiency in the economy signifies that all the production functions are optimal, and the firms are operating at the level of the production frontier. However, if the markets are imperfect, producers would still find themselves below the production frontier.

An output-oriented measurement of technical efficiency gives the technical efficiency of a farmer i as follows:

$$\boldsymbol{E}_i(x, y) = \left[\max \phi : \phi y \leq f(x_i)\right]^{-1} \qquad (5)$$

Parameter ϕ is the expansion of maximal output with a set of inputs x_i.

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[8] Agricultural productivity can generally be broken down into two elements, one dynamic and the other static. The first element is linked to technical progress and the second to productive efficiency. To examine the first element, it is necessary to have a chronological series at our disposal. Our data will allow us to have a temporal dimension, thus only the productive efficiency of a farm can be examined.

Following Kumbhakar and Lovell (2000), equation 5, applied in an econometric model gives:

$$Y_i = f(X_i, \beta)\, e^{-W_i} \tag{6}$$

Whereby Y_i is the real scalar of output, X_i is a vector of inputs used by the producer $i = 1, \ldots\ldots, N$ and $f(X_i, \beta)$ is the production frontier[9] whereby β is a vector of the technological parameters to be estimated. W_i is a random variable that is non-observable and non-negative, associated with technical inefficiency in production, which follows an arbitrary distribution.[10]

According to Aigner et al. (1977), and Meeusen and Van den Broeck (1977), a Stochastic production frontier is used in a way that the error term has two parts: random shocks V_i (which are non-attributable to the relationship between inputs and outputs) and inefficiency U_i [11]. Consequently, equation 6 becomes:

$$Y_i = f(X_i, \beta)\, e^{-U_i} . e^{V_i} \tag{7}$$

Whereby V_i represents the random shocks that are assumed to be independent and identically distributed with a normal distribution and a mean of zero and with an unknown variance. Using this hypothesis, a farmer whose performance is below the frontier is not totally inefficient because such inefficiency could very well be as a result of random shocks (such as climatic effects).

Because $\boldsymbol{E}_i$ is an output-oriented measurement of technical efficiency, a measurement of $\boldsymbol{E}_i$ is given as:

$$\boldsymbol{E}_i = \frac{\mathbf{P}\ d_{obs}}{\mathbf{P}\ d_{\max}} = \frac{f(X_i, \beta)\, e^{-U_i} . e^{V_i}}{f(X_i, \beta)\, e^{V_i}} = e^{-U_i} \tag{8}$$

Technical efficiency is thus estimated using the Stochastic frontier model given in equations 7 and 8.

The objective of the creation of the Stochastic frontier model is not only to determine the scores of technical efficiency but also to study the factors that characterize differences in efficiency. Drawing from Kumbhakar et al. (1991), Huang and Liu (1994), and Battese and Coelli (1995), the equation on production inefficiency in relation to these factors could be formulated as follows:

$$U_i = Z_i \beta + \varepsilon_i \tag{9}$$

Whereby Z_i is a vector of socio-demographic variables, including age, household size, membership of an association, use of enhanced seeds, the selling price of maize,

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[9] The production frontier has the traditional parameters of monotoneity, continuity and concavity (Fuss and McFadden, 1978).

[10] We will choose half-normal and exponential distributions as alternatives.

[11] A deterministic frontier implies a singular error term, which is inefficiency. Frontier deviation is uniquely as a result of inefficiency. The frontier gap is solely due to inefficiency.

access to markets, non-agricultural income, access to extension services, contact with an NGO, access to finance (formal or informal), literacy status, and the production zone. β is the vector of parameters to be estimated and ε_i is the error term, which follows truncated normal distribution defined by $\varepsilon_i \leq -Z_i\beta$.

The estimation of the vector of parameters β has been the subject of debate in efficiency studies. The most utilized procedure consists in the first place of an estimation of efficiency indexes and, in the second stage, of proceedings to conduct a regression against the various factors suspected to be present. Nonetheless, when Ray (1988) and Kalirajan (1991) defended this two-step procedure, Kumbhakar et al. (1991) and Battese et al. (1996) criticised its use, arguing that it violates one of the primary hypotheses according to which "the effects of inefficiency are identical and independently distributed at the Stochastic frontier". Battese and Coelli (1995) proposed a one-step model in which the effects of inefficiency are a function of diverse observable variables such as age, education, access to extension services, types of seeds used, etc. Despite these criticisms, the two-step procedure remained popular in research on factors affecting efficiency indexes. This popularity is borne out of the fact that there is no exhaustive list of inefficiency determinants.

To estimate technical efficiency of farmers, the current study adopts the two-step procedure. Thus, the various efficiency indexes are in the first place determined with the use of a Stochastic frontier method and, secondly, the factors that affect these efficiency indexes will be examined. The choice of a regression model for the second part of the analysis is not an easy one. The standard approach that consists of the use of a doubly censored Tobit model (in 0 and 1) to model the scores is debatable. Indeed, the accumulation of observations of specific units is a natural consequence of the way in which efficiency scores are defined, rather than the results of censoring. Also, there is the question of whether the doubly censored Tobit model differs from that of scores as generally efficiency scores of 0 are never recorded. This difference is particularly pertinent because the application of the doubly censored Tobit model in this context brings us back to the estimation of a Tobit with a censored score pertaining to $-\infty;1-\infty;1$ (Ramalho et al., 2009; Ramalho et al., 2010). Thus, the Fractional Regression Model developed by Papke and Wooldridge (1996) is used to estimate the second step because the efficiency scores are constitutive of the proportions.[12].

The Stochastic frontier model requires a predetermined specification of a function that is generally in use, such as Cobb-Douglas and Translog. The Cobb-Douglas function is a particular form of the translog production function whereby the coefficient of the squared term and or interaction of the variables of the inputs of the translog function are assumed to be equal to zero. The translog frontier is susceptible to multicollinearity in as much as it may be the form that would be the most flexible (Thiam et al., 2001). The Cobb-Douglas production function is preferred despite its restrictive properties because its coefficients directly represent the effect of

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[12] For more details, see Baum (2008), The Stata Journal, 8 Number 2, pp. 299-303 and Wooldridge (2010) pp. 748-755.

a variation in the quantity of inputs on the output because they are easier to estimate and interpret than the translog frontier (Coelli and Battese, 1998). Thus the Cobb-Douglas frontier is the preferred model for this study.

The traditional Cobb-Douglas Stochastic production frontier model is used to estimate technical efficiency in the following general form (we use a negative sign to show that the term-U_i represents the difference between the most efficient firm on the frontier and the observed firm) (Christensen et al., 1971):

$$\ln(Y_i) = \beta_0 + \sum_j \beta_j \ln(X_j) - U_i + V_i \tag{10}$$

Whereby $i = 1,2,\ldots\ldots,N$ is the unit of observation of the farmer; $j;k = 1,\ldots\ldots.,9$ are the inputs used; $\ln(Y_i)$ is the logarithm of output of the farmer i; $\ln(X_{ij})$ is the logarithm of inputs used by the j farmer; and β_0; β_j are the parameters to be estimated. Furthermore, the production frontier necessitates monotonicity and concavity. These hypotheses must be verified retrospectively by using estimated parameters for each data point.

The final empirical model in this case is:

$$\ln(Y_i) = \beta_0 + \beta_1 \ln(X_{i1}) + \beta_2 \ln(X_{i2}) + \beta_3 \ln(X_{i3}) + \beta_4 \ln(X_{i4}) + \beta_5 \ln(X_{i5}) + \beta_6 \ln(X_{i6}) + \beta_7 \ln(X_{i7}) + \beta_8 \ln(X_{i8}) + \beta_9 \ln(X_{i9}) - U_i + V_i \tag{11}$$

With Y_i being the maize yield for the producer (in kg/ha) for the producer i, X_1 = the quantity of manure used (in kg/ha), X_2 = the quantity of NPK fertilizer used (in kg/ha), X_3 = the quantity of seeds used (in kg/ha), X_4 the quantity of labour used in manhour/day per hectare (in hj/ha), X_5 = the quantity of pesticides used (in L/ha), X_6 = the area cultivated (in ha), X_7 = the amount of formal financing obtained (in FCFA), X_8 = the amount of informal credit obtained (in FCFA) and X_9 = the climate (the amount of rainfall).

We have used, for purposes of this study, secondary data that is mainly data on the cultivation of maize, rice and vegetables collected by PAPA-INRAB[13] in collaboration with the sub-regional programme of Integrated Production and Pest Management in 2012. These data give information on the characteristics, production practices, harvest and post-harvest practices of farm holdings that produce maize, rice and vegetables in six districts of Benin, namely: Collines, Couffo, Mono, Ouémé, Plateau and Zou. More precisely, the data focuses on 266 farmers and they provide economic data such as the price in FCFA of inputs and output, the quantity in kilogrammes of inputs (fertilizer, manure, labour, etc) and output, whether they are members of an association or not, whether or not they are in contact with an agricultural extension officer, etc. They also provide information on household characteristics such as the

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[13] National Institute of Agricultural Research of Benin

members of a household, gender, level of education and the age of the head of a household, his/her status, the distance to the farm from their domicile, etc. Table 1 illustrates the definition of variables used in our models and Table 2 presents the main characteristics of the variables and the sample size.

Table 1: Definition of the variables that are used in our models

Variable	Definition
Gender of the farmer	1 if the farmer is male; 0 if not
Age of the farmer	Age of the farmer in years
Age squared	Squared age of the farmer
Climate	Measurement by rainfall
Literacy	1 if the farmer is literate; 0 if not
Household size	The number of living individuals in the household
Amount of formal credit	Amount of formal credit obtained for the agricultural season
Amount of informal credit	Amount of informal credit obtained for the agricultural season
Area cultivated	Sown area in hectares (ha)
Price of maize	Selling price of maize
Membership of a farmers' association	1 if the farmer is a member of a farmers' association; 0 if not
Use of enhanced seeds	1 if the farmer uses enhanced seeds; 0 if not
Contact with an extension officer	1 if the farmer uses the services of an extension officer, 0 if not
Contact with an NGO	1 if the farmer is in contact with an NGO that operates within the agricultural domain; 0 if not
Literacy x contact with an extension officer	1 if the farmer is literate and uses extension services; 0 if not
Literacy x contact with an NGO	1 if the farmer is literate and in contact with an NGO; 0 if not
Access to a farm	1 if the farmer has access to their farm throughout the season in the year; 0 if not
Cotton growing zone of Benin	1 if the farmer is in the cotton growing zone of Benin; 0 if not
Terres de barre zone	1 if the farmer is in Terres de Barre area; 0 if not.
La Dépression zone	1 if the farmer is in the la Dépression zone; 0 if not.
Pêcheries zone	1 if the farmer is in the Pêcheries zone, 0 if not.
Quantity produced	Quantity of maize produced in kg/ha
Pesticide	Quantity of pesticide used in L/ha
NPK	Quantity of NPK fertilizer used in kg/ha
Manure	Quantity of manure used in kg/ha
Seeds	Quantity of seeds used in kg/ha
Labour	Quantity of manpower used in people/day

Table 2: Descriptive statistics on the variables used in the production efficiency model

Gender	Occurence	Percentage	Literacy x contact with an NGO	Occurence	Percentage
Male	177	87.19	Yes	6	2.96
Female	26	12.81	No	197	97.04
Total	203	100.00	Total	203	100.00
Membership of an association	Occurence	Percentage	Use of enhanced seeds	Occurence	Percentage
Yes	20	9.85	Yes	30	14.78
No	183	90.15	No	173	85.22
Total	203	100.00	Total	203	100.00
Access to markets	Occurence	Percentage	Literacy x contact with an extension officer	Occurence	Percentage
Yes	152	74.88	Yes	10	4.93
No	51	25.12	No	193	95.07
Total	203	100.00	Total	203	100.00
Variable	Number of observations	Average	Standard deviation	Minimum	Maximum
Age of the farmer	203	45.0689	13.9676	17	89
Age squared	203	2225.345	1365.484	289	7921
Climate	203	1112.041	107.9223	963.7	1288.9
Household size	203	6.9655	3.8504	1	25
Area cultivated	203	0.9249	1.0231	0.03	5.5
Price of maize	203	173.7438	29.5682	115	220
Quantity produced	203	1441.466	665.7349	338	3250
Pesticide	203	53.8547	19.7716	1	65.5178
NPK	203	3.6287	2.1456	0.3333	18
Manure	203	18.1301	45.5417	2.7183	275
Seeds	203	31.3876	32.8388	0.1667	137.5
Amount of formal credit	203	21280.79	112524.3	0	950000
Amount of informal credit	203	2561.586	11228.49	0	80000

4.0 Results and Discussions

This section gives an estimation of the scores of technical efficiency of the farmers, then examines the determinants of their level of productive efficiency.

4.1 Estimation of the Level of Technical Efficiency of the Farmers

The estimation parameters of the production function were obtained using the Cobb Douglas function and the OLS method in the first stage, then the Stochastic frontier method in the second stage. We defer the marginal mean effects for the two models from the first stage. Table 3 presents the results of the production function by OLS and by SFA. The OLS results are presented in the column marked (1) whereas those of the Stochastic function are given in the column marked (2).

By focusing on the production function model in column (2), we observe that the lambda coefficient is significant at 1%. This indicates the presence of technical inefficiency among the sampled farmers. The potential yield has not yet been attained. This lambda value also shows that farmers could achieve the reported yields with a lower quantity of inputs, and brings out the problem of the capacity of the farmers in terms of the optimal combination of production inputs.

The results show that inputs such as manure, NPK fertilizer, seeds, labour, pesticides, sown area of the farm, and climate have a significant effect on the production of farmers. Indeed, the correlated coefficient to manure is 0.0805, which indicates that the average effect of manure on yield is close to 8.05%. The coefficient associated with NPK manure is 0.1814, which indicates that the average effect of NPK manure on yield is close to 18.14%. These results are not very far from those arrived at by Adegbola et al. (2008). The yield is thus positively susceptible to variations in the quantity of NPK fertilizer. The quantity of seeds used with a coefficient of 7.03% has a positive and significant effect on the yield of the producer. It is also the same for manpower used, pesticides and climate, which have an average effect on yield of 0.0087, 0.0617 and 0.6705, respectively.

The sown area of the farm with a coefficient of 5.45% has a negative and significant impact on yields. These results are not very far from those arrived at by Adegbola et al. (2008) who found an average effect of 21% for fertilizer. The same results were arrived at by Koirala et al. (2013) and Mohammed and Saghaian (2014).

Table 3: Estimations of the efficiency model

Standard errors in parentheses

Variables	Production function model OLS (1)	SFA (2)
Quantity of manure	0.1161*** (0.030)	0.0805*** (0.025)
Quantity of NPK	0.2810*** (0.082)	0.1814*** (0.055)
Quantity of seeds	0.0882** (0.039)	0.0703*** (0.024)
Quantity of labour	0.0039 (0.006)	0.0087* (0.005)
Quantity of pesticide	0.0987*** (0.037)	0.0617** (0.027)
Sown area	0.0309 (0.031)	-0.0545* (0.031)
Amount of formal credit	0.0065 (0.013)	0.0117 (0.008)
Amount of informal credit	0.0211** (0.010)	0.0074 (0.010)
Climate	1.1492*** (0.372)	0.6705** (0.297)
Sigma2v		-3.1809*** (0.379)
Sigma2u		-1.3412*** (0.223)
Lambda		2.5089*** (0.086)
Sigma2		0.3031*** (0.050)
Constant	-0.8128 (2.580)	3.1505 (2.066)
Observations	203	203
R-squared	0.162	
LL		-133.71591
Wald Chi2(9)		37.79

*** p<0.01, ** p<0.05, * p<0.1

4.2 Distribution of Efficiency Scores of Farmers

The frequency scores for the estimation of technical efficiency indexes of farmers are presented in Table 4. The average score of technical efficiency of farmers in our sample is 65.40%, which indicates the presence of technical inefficiency among farmers. The level of technical efficiency varies between 20.47% and 93.46%. We assume that a farmer is said to be effective when he obtains an index that is higher or equal to the average efficiency score (65.40%). Thus, according to this logic, only 61.08% of farmers in our sample are technically efficient.

Table 4: Distribution of the frequency of technical efficiency of farmers

Efficiency (%)	Technical efficiency Occurrence	Percentage
≤ 25	22	10.84
26 – 49	45	22.17
50 – 60	16	7.88
61 – 70	22	10.84
71 – 80	34	16.75
81 - 90	55	27.09
91 - 100	9	4.43
Mean	65.40	
Minimum (%)	20.47	
Maximum (%)	93.46	

4.3 Breakdown of Efficiency Scores According to Agro-ecological Zones

In this sub-section, we present farmers' levels of efficiency according to the different agro-ecological zones. Thus, we present the efficiency levels of farmers in the cotton growing zone of Central Benin, the Terres de Barre zone, Dépresssion zone and Pêcheries zone, respectively. This breakdown of efficiency scores according to the agro-ecological zones (Table 5) reveals that farmers in the Dépression zone are more technically efficient than farmers in the other zones. This shows that efforts towards improvement in the technical efficiency levels of farmers should, as a priority, be directed towards farmers in the Pêcheries zone, who have the lowest levels of technical efficiency, all the while not neglecting the other zones.

The mean score for technical efficiency of farmers in the cotton growing zone of Benin is 65.34%, which indicates the presence of technical inefficiency for these farmers. In this zone, the level of technical efficiency varies from 22.16% to 93.46%. Only 58.87% of farmers in this zone are technically efficient.

The average score of technical efficiency of farmers in the Terres de Barre zone is 74.23%, which indicates the presence of technical inefficiency among these farmers. In this zone, the level of technical efficiency varies between 41.06% and 89.70%. Only 59.09% of farmers in this zone are technically efficient.

The average score of technical efficiency of farmers in the Dépression zone is 76.48%, which indicates the presence of inefficiency among these farmers. In this zone, the level of technical efficiency varies between 50.28% and 91.51%. Almost 53.85% of farmers in this zone are technically efficient.

The average score of technical efficiency of farmers in the Pêcheries zone is 50.07%, which indicates the presence of inefficiency among these farmers. In this zone, the level of technical efficiency varies between 20.47% and 90.95%. Only 41.94% of farmers in this zone are technically efficient.

The Terres de Barre and Dépression zones have the highest scores in terms of technical efficiency. This could be explained through the fact that they are comparable from the climatic point of view, and have better soil quality than other areas whose main farming activities are mostly cotton growing and fishing.

Table 5: Occurrence of technical efficiency among farmers in the various agro-ecological zones of Benin

	Cotton growing zone of Benin Technical		Terres de Barre zone Technical		La Dépression zone Technical		Pêcheries zone Technical	
Efficiency (%)	Occurrence	%	Occurence	%	Occurrence	%	Occurrence	%
< 50	39	31.45	5	22.73	3	11.54	20	64.52
50 – 100	85	68.55	17	77.27	23	88.46	11	35.48
Mean	65.34		74,23		76.48		50.07	
Minimum (%)	22.16		41.06		50.28		20.47	
Maximum (%)	93.46		89.70		91.51		90.95	

4.4 Breakdown of Efficiency Scores According to the Type of Seeds Used

The breakdown of efficiency scores of farmers according to the type of seeds used is given in Table 6. A close study of Table 6 shows that farmers who use enhanced seeds have a statistically higher average score of technical efficiency than those farmers who use traditional seeds. This shows that enhanced seeds should be made more accessible to farmers and at a lower cost to improve efficiency levels. Among farmers who use enhanced seeds, 86.67% are technically efficient against 63.58% of those who use traditional seeds. This confirms the importance of the use of enhanced seeds in the improvement of farmers' yields.

Table 6: Breakdown of efficiency scores according to the types of seeds used

4.5 Factors Affecting the Level of Technical Efficiency of Farmers

To identify the factors that determine the efficiency levels of farmers, we first of all use the Fractional Regression Model (FRM) to examine the robustness of the identified factors. We thereafter use the GLM method, then the OLS method. The results of these different estimations are given in Table 7. The negative signs of the parameters in Table 7 indicate that the associated variables have a positive effect on technical efficiency of the producer because the dependent variable is the score of technical inefficiency.

The results in this table indicate that the significant determinants in regard to technical inefficiency of farmers are: the gender of the farmer, the use of improved seeds, the selling price of maize, the percentage share of non-agricultural income, contact with an extension agent, access to finance, and the production zone.

According to the results, a male farmer has a lower probability of being technically inefficient compared to a female farmer, all other factors remaining constant. This result could be explained by factors related to the life cycle of the household. Households headed by women have a tendency to have more members than those headed by men (8 against 6). Consequently, female heads of households could spend less time in remunerative production activities. Another interpretation is that male heads of households have higher management competencies and have fewer constraints in terms of finding labour in their activities of agricultural production. Women are generally less capable than men of being guaranteed land rights or having more access to land. These rigidities in terms of land rights and labour in the household or in the community, together with the high control typically exerted by men, contribute to women's low technical efficiency.

Furthermore, farmers who use enhanced seeds have a higher probability of being technically efficient compared to those who use traditional seeds, all other factors remaining constant. This result could be explained by the fact that the use of enhanced seeds translates into an improvement at the production level and therefore to technical efficiency. These results agree with those arrived at by Adegbola et al., (2008).

The higher the selling price of maize, the higher the probability that the farmer will be technically efficient. This demonstrates the important role played by price stabilization policies so that the food crop is sold within a stable price range. The more the price is relatively stable, the more confident the farmer is, and this would have an impact on improving their yield.

Non-agricultural income has a negative and significant impact on technical inefficiency of farmers. If the capital markets work as they should, the introduction of other streams of income should not affect technical efficiency (Chavas et al., 2005). Our results indicate the presence of a poor functioning capital/credit market whereby liquidity constraints are surmounted through income generated from non-agricultural activities.

The results also show that farmers who are both literate and in contact with an NGO operating within the agricultural sector have a higher probability of being technically efficient compared to those who are not, all other factors remaining constant. This could be explained through the fact that education could increase access to information and the capacity of farmers to adjust and as a result their capacity to apply information and training offered by NGOs in their farming activities. Furthermore, this could help them adapt to modern agricultural technology, which would allow them to attain the highest production level with the same level of inputs. This result agrees with those arrived at by Ogundari (2013), Costa et al. (2013), de Magalhães et al. (2011), Asefa (2011), Idiong (2007), Liu and Myers (2009) and Rahman (2003).

A farmer who is literate and in contact with an extension agent has a higher probability of being technically inefficient compared to one who is not, all other factors remaining constant. This result is contrary to our expectations, but the result could be explained by the fact that in the 1960s, agricultural extension services were provided by the government. After 1990, the government decided to suspend support services to farmers, thus each farmer was obliged to meet the costs related to services provided by extension agents each time the need arose. Thus, extension services slowly disappeared from the production process because farmers could not afford them.

With the coming of a new regime in 2006, the new government decided to reintroduce extension services. The political will led to the recruitment of young extension agents who had just been freshly trained but with no working experience. This led to a confidence crisis between the extension agents and the farmers who felt that they were more experienced and more knowledgeable than the agents. This confidence crisis led to a situation whereby farmers did not follow instructions given by the extension officers to the letter. The result could also be explained by lack of depth in the suggestions given by the extension agents, or through their lack of assiduity. However, it is also possible that the farmers could assume that certain directions given for particular circumstances are applicable in all situations.

Another possible situation is that agricultural extension officers do not take the endogenous realities into account and the specificities related to each intervention zone when advising farmers. This poses a problem in terms of contextualizing the quality of services provided by extension officers. A strategy aimed towards improving outreach services is, therefore, necessary to achieve the expected results.

Access to informal credit has a negative and significant effect on the level of technical efficiency of farmers. The same could be said for access to formal credit, with a significant effect, however. This indicates that farmers with access to credit have a higher probability of being technically efficient compared to other producers. These results could be explained through the fact that availability of finance (especially informal credit, which is more accessible to farmers in Benin) overcomes the liquidity constraint and allows farmers to purchase their inputs within an opportune period, which they cannot afford to do using their own resources, to improve their use of agricultural inputs, and which leads to higher efficiency. These results are in agreement with those arrived at by Asefa (2011).

Farmers from the Pêcheries zone have a higher probability of being technically inefficient compared to farmers from other zones, all other factors remaining constant. This result could be explained by the quality of soils found in each agro-ecological zone. It shows that policies for the improvement of the efficiency of farmers should take into account the specificities of each zone to have a better impact in defining the quality of inputs that corresponds to each agro-ecological zone.

Table 7: Factors affecting the level of technical inefficiency of farmers

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Variables	(1) FRM	(2) GLM	(3) OLS
Gender of the farmer (male=1)	-0.3897**	-0.0863***	-0.0863**
	(0.158)	(0.033)	(0.035)
Age of farmer	0.0332	0.0070	0.0070
	(0.027)	(0.006)	(0.006)
Age squared	-0.0005	-0.0001	-0.0001
	(0.000)	(0.000)	(0.000)
Household size	0.0072	0.0017	0.0017
	(0.016)	(0.004)	(0.004)
Membership of an association (Yes=1)	0.0889	0.0198	0.0198
	(0.187)	(0.043)	(0.045)
Use of improved seeds (Yes=1)	-0.6145***	-0.1263***	-0.1263***
	(0.186)	(0.036)	(0.038)
Selling price of maize	-0.0071***	-0.0015***	-0.0015***
	(0.002)	(0.000)	(0.001)
Access to farm	0.3930	0.0855	0.0855
	(0.254)	(0.053)	(0.055)
Percentage share of non-agricultural income	-0.0530*	-0.0106*	-0.0106*
	(0.032)	(0.006)	(0.006)
Literacy x contact with an extension agent	0.7021***	0.1430**	0.1430**
	(0.264)	(0.059)	(0.062)
Literacy x contact with an NGO	-1.0032***	-0.1951***	-0.1951***
	(0.240)	(0.048)	(0.050)
Access to informal credit (Yes=1)	-0.3828*	-0.0919*	-0.0919*
	(0.208)	(0.050)	(0.052)
Access to formal credit (Yes=1)	-0.2388	-0.0526	-0.0526
	(0.227)	(0.053)	(0.056)
Cotton growing zone of Benin	-0.8415**	-0.2004***	-0.2004**
	(0.349)	(0.076)	(0.079)
Terres de Barre zone	-1.4072***	-0.3176***	-0.3176***
	(0.293)	(0.064)	(0.066)
Dépression zone	-1.5676***	-0.3464***	-0.3464***
	(0.386)	(0.084)	(0.087)
Constant	-1.8744**	0.1114	0.1114
	(0.775)	(0.168)	(0.175)
Observations	203	203	203
R-squared			0.270

5.0 Conclusion and Policy Implications

Despite the importance of maize in Benin's economy, and in the feeding of the population, there has been practically no study on the efficiency of maize producers in Benin. This study uses the production frontier to estimate the levels of technical efficiency of farmers using input and output data from 203 maize farmers from six districts of Benin, namely: Collines, Couffo, Mono, Ouémé, Plateau and Zou. The results demonstrate that the average level of technical efficiency is 65.40%. Among the farmers sampled, 61.08% are technically efficient. A breakdown of efficiency scores according to agro-ecological zones shows that farmers in the Dépression zone are more technically efficient than those from other zones. The results also indicate that farmers who use enhanced seeds are statistically more efficient than the rest.

The analysis in the second stage, whereby the inefficiency scores have been regressed using specific characteristics of farmers by using not only the Fractional Regression Model (FRM), but also the GLM and OLS methods to examine the robustness of the results, reveals that the gender of the farmer, the use of enhanced seeds, the selling price of maize, the percentage share of non-agricultural income, contact with an extension agent, contact with an NGO, access to finance, and the production zone determine the efficiency level of the farmers. Variables such as the gender of the farmer, the use of enhanced seeds, the selling price of maize, the percentage share of non-agricultural income, contact with an NGO, access to credit (informal), and the production zone have a positive role in attaining the production frontier.

In terms of policy implication, the results show that the policy of distribution of improved seeds and fertilizer by the government helps farmers to be more efficient contrary to that of using extension agents. Indeed, this distribution policy involves: (i) the development and supply of more performant and adaptive seed varieties; (ii) the production of pre-basic and basic seeds and distribution of certified seeds; (iii) the formulation and implementation of incentive provisions (exoneration, subsidies) for the importation and distribution of fertilizer; (iv) allocating distribution points for seeds and fertilizer in each community; (v) providing information for farmers on the availability of specific fertilizers and seeds; and (vi) the improvement of the stockage and conservation systems for seeds at the distribution points (palettes, refrigerators, thematic training, etc). These results lead us to recommend that the government reduce the resources used for extension services and instead focus on policies of distribution of enhanced seeds and invest more in research on improved seeds. This assumes that sufficient resources will be made available to research centres specialized in the production of enhanced seeds to allow farmers to access them at reasonable costs.

A policy for the improvement of agricultural extension services, therefore, becomes indispensable and this could for example entail hiring extension agents on a two-tiered employment contract, which at one level is that of a fixed wage and the other on the performance of the level of productivity of the farmers that they support. Thus, the constant quest for higher earnings would lead them to work harder in their support and monitoring of farmers. A sensitization of farmers is also necessary to create an atmosphere of confidence between extension agents and farmers.

The government should also create incentives at the institutional level that would increase credit supply. An agricultural credit fund would allow farmers to have access to agricultural credit at preferential rates and at the same time correct the imperfections in the capital and/or labour markets.

Other actions that allow an improvement of the efficiency level of farmers should also be implemented, for example investment in the education and training of farmers. Policies related to the stabilization of the selling price of maize and the maintenance of rural roads should also be developed to provide a guarantee to farmers in terms of the transport of their produce. Policies of adaptation to effects of climate change should be strengthened, for example through the practice of irrigation.

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