An Estimation of the Determinants of Efficiency of Rice Farmers in Benin: A Case Study of the Departments of Mono and Couffo

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List of abbreviations

CARDER	Centre d'Action Régionale pour le Développement Rural
CRS	Constant Returns to Scale
CRR	Regional Council of Rice Growers
DEA	Data Envelopment Analysis
FAFA-MC	Support Project for the Agricultural Sector of Mono and Couffo
INSAE	National Institute of Statistics and Economic Analysis
MAEP	Ministry of Agriculture, Livestock and Fisheries
PUASA	Emergency Aid Programme for Food Security
PSDSA	Strategic Plan for the Development of the Agricultural Sector
SDGs	Sustainable Development Goals
SNDR	National Strategy for Rice production
SONAPRA	National Association for Agricultural Promotion
USDA	United States Department of Agriculture
VRS	Variable Returns to Scale

Abstract

Rice is an important component in the quest for food security in Benin, but its production remains low and thus needs to be optimized. This study estimated technical as well as allocative efficiency and identified the sources of the inefficiency of rice farmers in Benin, with specific focus on the departments of Mono and Couffo. The study used secondary data obtained from the Ministry of Agriculture, Livestock and Fisheries. The data covers 210 rice farmers evenly spread out within the departments of Mono and Couffo. The Cobb-Douglas production frontier method was used to measure the level of technical efficiency of farmers, while allocative efficiency was examined using the marginal product value method. The results reveal that the technical efficiency of producers is at 78%, and that there are therefore possibilities of increasing rice production. The sources of inefficiency are age, sex, the level of education and access to finance. The results also revealed the existence of allocative inefficiency in rice cultivation. Manpower is overused whereas other production factors such as seeds, pesticides, and fertilizer are underutilized. Allocative efficiency is explained by sex, age, the area sown, the type of crop, and access to finance. These results indicate that rice farmers in the departments of Mono and Couffo would benefit from adopting the best agricultural practices such as the use of fertilizer, agro-chemical products, and irrigation.

Key words: *Efficiency; Rice production; Mono; Couffo; Benin.*

JEL classification: *D13; D61; Q12.*

1. Introduction

In Benin, the introduction of rice among the staples goes back to the colonial period, but rice farming really started in the post-independence period, during the 1960s with the establishment of state-run rice farms. Due to an increase in the population of Benin by 2.9% between 1979 and 1992, and by 3.2% between 1992 and 2002, and by 3.5% between 2002 and 2013 (National Institute of Statistics and Economic Analysis [INSAE], 2013), the national consumption of rice increased by 7,000 tonnes in 1960 to 265,000 tonnes in 2010 and to 729,000 tonnes in 2017 (United States Department of Agriculture [USDA], 2018). Rice demand increased, and the average consumption which was at the level of 3kg-4kg per capita and per year in the 1960s increased to 12kg per capita and per year in 2004 then 25kg-30kg per capita and per year in 2011 (National Strategy for Rice production (SNDR, 2011) and to 45.7kg per capita and per year in 2017 (Strategic Plan for the Development of the Agricultural Sector [PSDSA], 2018). Despite the increase in national production of paddy rice from 1,000 tonnes in 1960 to 80,000 tonnes in 2010 and to 179,000 tonnes in 2017 (USDA, 2018), the national production of rice is still not sufficient to meet the local demand. It only covers 25% of rice consumption (USDA, 2018). The consumption gap is therefore filled through imports (including the percentage share of re-exportation) which has increased from 6,000 tonnes in 1960 to 195,000 tonnes in 2018 (USDA, 2018). Rice imports lead to heavy losses in terms of foreign exchange, which was estimated at US$293 million in 2018 (USDA, 2018).

The Strategic Plan for the Development of the Agricultural Sector (PSDSA, 2018) for Benin, listed the promotion of rice cultivation among the priority sectors that need to be addressed. Thus, rice is one of the food crops the government of Benin is depending upon to ensure food security and poverty reduction so as to meet the Sustainable Development Goals (SDGs). The set target is to achieve rice cultivation of 72,960 tonnes of rice paddy by 2007 and 600,000 tonnes (equivalent to 385,000 tonnes of white rice) as from 2015 in order to ensure self-sustainability in rice production and also have a surplus for trade exchanges by 2018. However, the national production of rice, estimated at 234,145 tonnes of paddy in 2015, is far from the objective of 600,000 tonnes of paddy in 2015. Rice yields have oscillated around three tonnes per hectare since 2003. This is far below the potential yields, which are estimated at between three tonnes and 10 tonnes per hectare depending on the varieties and the production system (Ministry of Agriculture, Livestock and Fisheries [MAEP], 2009). This situation demonstrates that there are tremendous opportunities for the improvement of rice yields in Benin.

An increase in the cultivated area, the promotion of good-quality rice seeds, access to fertilizer and to agro-chemical products, an improvement of access to finance, the improvement of agricultural equipment and strengthening of outreach services (SNDR, 2011) are strategies that the governments have used in order to improve access by small-scale farmers to production resources and thus increase rice production in Benin. In regard to these actions, this study addresses the problem of the efficient allocation of production resources. This point of view has been supported by authors of previous studies (Yabi, 2009; Kinkingninhoun-Medagbe et al, 2010; Singbo and Lansink, 2010; Amoussouhoui et al, 2012; Zannou et al, 2018) who demonstrated that there is at least 16% inefficiency in regard to rice production in Benin. For example, Yabi (2009) evaluated technical efficiency of rice producers in Benin at 0.82. Kinkingninhoun-Medagbe et al (2010) estimated technical efficiency of producers of irrigated rice at 0.84. Singbo and Lansink (2010) demonstrated that there is 35% inefficiency in rice production in lowland rice production in Benin. These studies clearly reveal that rice producers in Benin would benefit from a better and more efficient use of production resources.

Rice cultivation was introduced to the departments of Mono and Couffo in 1976. Rice cultivation is mostly undertaken on small-scale units that are run by families. Besides these family-run units, there is developed land, whereby irrigation utilizing either drip irrigation or total submersion in water is used. Most of these rice farms are located in lowlands, whether developed or not. Rice cultivation has not really picked in the region, despite the possibility of transforming this to large-scale production given the abundance of water resources. From an evaluation of the performance of rice growing areas in various departments of Benin, we observe that the region of Mono-Couffo recorded the lowest productivity. The total production in the region was 3,026 tonnes in 2015 against 6,032 tonnes in 2014 and 971 tonnes in 2001 (MAEP, 2018). However, in departments with large-scale rice production such as Atacora, Alibora and les Collines, rice production in 2017 was estimated at 143,507 tonnes, 130,193 tonnes and 49,456 tonnes, respectively (MAEP, 2018). Various interventions through the "Emergency Aid Programme for Food Security" (PUASA) and the "National Association for Agricultural Promotion (SONAPRA)" in the departments of Mono and Couffo contributed to an increase in the total cultivated area from 316 hectares in 2001 to 1,101 hectares in 2015 (MAEP, 2018), but the level of production remains low. The food balance sheet of the Mono-Couffo region reveals that in regard to low consumption, rice remains at a deficit by 5,932 tonnes in Mono and 7,336 tonnes in Couffo in 2017. This deficit is perennial and impacts upon meeting the demands of vulnerable groups. This leads to serious problems of having a malnourished population and lagged growth of children.

Thus, despite being a rice producer, Benin basically depends on foreign produce to meet its local demand for rice. In order to lower this dependence on global food markets, and so as to allow for rice to effectively play its role as a staple and thus contribute to food security and poverty reduction, it is important to optimize the systems of rice production; in other words, to improve the performance of production factors. Because agricultural land is not infinite, it is important to improve the efficiency of existing production factors so as to increase rice production. A study aimed at examining the efficiency of rice farmers and their determinants is therefore essential in order to put appropriate policies in place so as to support future endeavours that will promote the development of rice production in Benin in general and in the departments of Mono and Couffo in particular.

Our study contributes to economic research in various ways. Firstly, it provides support to future policies that will promote rice farming. This comes at an important moment because the domestic levels of rice production remain insufficient to meet the needs of the local population. Secondly, none of the previous studies (Yabi, 2009, Kinkingninhoun-Medagbe et al, 2010; Singbo and Lansink, 2010; Amoussouhoui et al, 2012; Zannou et al, 2018) on the efficiency of rice farmers in Benin were carried out in the departments of Mono and Couffo. Thirdly, in terms of empiricism, most studies did not take the matter of the heterogeneity of the regions into account. This study thus aims at filling these gaps. In order to do so, it aims at providing answers to the following questions: What are the levels of technical and allocative efficiency of rice farmers? Which are the efficiency factors for rice farmers? The overall objective of this study, therefore, is to identify the factors which influence the technical and allocative efficiency of rice farmers in Benin. More specifically, the study aims to: (1) Estimate the level of technical and allocative efficiency of rice farmers; (2) Identify the determinants of efficiency of rice farmers in Benin; and (3) Determine to what level the models of technical and allocative efficiency are the same in the two regions (Mono and Couffo).

2. Literature review

The notion of efficiency

The term efficiency is broad and varied in meaning. It includes a set of notions that are at times specific such as those of production, profits, costs or price, etc. Literature comprises several definitions that more or less closely resemble. Efficiency has three components, namely, technical efficiency, allocative efficiency and economic efficiency. Farrell (1957) proposes the decomposition of economic efficiency into a technical component and an allocative component. It corresponds to the product of technical efficiency and allocative efficiency (Coelli et al, 1998). A farm is, therefore , economically efficient when it is both technically efficient and allocating production resources in an effective manner.

Technical efficiency measures the ability of a production unit to obtain the maximum of possible outputs from a given combination of inputs and production technologies, or its ability to obtain a given level of outputs from the smallest possible quantity of inputs. Koopmans (1951) was the first to suggest a formal definition of technical efficiency. According to him, a producer is technically efficient if an increase of whichever output does not require the reduction of at least one other output or an increase of at least one input. In other words, a technically efficient firm has to be at the production frontier of all its outputs. However, it is Farrell (1957) who defines efficiency in a more precise manner by disassociating all that which is of technical origins from all that which is of a poor choice in regard to the cost of inputs. Technical efficiency, in the spirit of Debreu's (1951) coefficient of utilization of resources measures the manner in which the entrepreneur combines production factors when the proportions of their utilization are given. There is technical inefficiency when one can obtain the same result with a lower quantity of inputs. Price efficiency is defined by the manner in which the entrepreneur fixes the proportions between the different inputs involved in the production combination. Thus, the term allocative efficiency is often used in place of that of price efficiency, often used by Farrell.

Allocative efficiency comes from the fact that production factors are not free, they come at a price. Due to this fact, in choosing their production programme, the firm must, in addition to technical parameters, take into account their relative prices in the market. Allocative efficiency thus measures the ability of the production unit to combine their inputs in optimal proportions taking into account their relative price in the market and the budget allocated to acquire them. Thus, for a family of combination factors that allow for the attainment of a given production level, the best allocative combination is that which is obtained at the lowest cost with the highest level of profit. Allocative inefficiency is, therefore, arrived at through the use of production factors in proportions that do not minimize costs by taking into account their price in the market.

Methods of measuring efficiency

Two methods are generally used in literature to measure efficiency. If the production frontier could be correctly represented by a function comprising of explicit parameters such as the Cobb-Douglas function or the Trans-log function, the approach used is described as parametric. However, if one considers that the process of production studies does not have an *a priori* well established functional form, the approach used is described as non-parametric. The distinction between the different approaches is thus close to the structure of the frontier (Amara and Romain, 2000; Coelli et al, 1998).

The non-parametric frontier approach (Farell, 1957; Coelli et al, 1998; Amara and Romain, 2000) assumed that the frontier is not related to a functional form and frontier isoquant is estimated through the input/output ratios of each firm. This non-parametric approach develops the two following steps in a similar manner (Piot-Lepetit and Rainelli, 1996; Coelli et al, 1998). The first step consists of developing a representation of technology from the corpus of available observations. Each farm is thus compared to other farms, including itself. Thus, if there is no remaining observation with the same factor endowment or also with a lower quantity of inputs, the farm under study belongs to the production frontier, and is considered as being technically efficient. Otherwise, it is included in the corpus of production possibilities and declared to be technically inefficient thus its name of a determinist approach. So as to calculate the efficiency of each farm, the next step consists of measuring the existing gap between each of the farms and the previously described production frontier. The described values are between 0 and 1. Thus, all farms situated on the frontier are given the value of 1 whereas the other firms obtain a score that is lower than 1, which would also be lower when the initial status of the farm is taken further away from the production frontier. This method of measuring technical efficiency of farms assumes that production technology is characterized by Constant Returns to Scale (CRS). However, it is possible to measure efficiency in terms of Variable Returns to Scale (VRS), in other words, the economies of scale.

The non-parametric approach uses the Data Envelopment Analysis (DEA) method introduced by Charnes et al (1978). The DEA method consists of the use of mathematical programming to produce a production frontier of fragments derived from the data set from production units. The DEA method allows for an estimation of the CRS or VRS methods. Coelli et al (1998) show the difference between the technical efficiency unit obtained through the use of the DEA method of the CSR type and that of the same farm through the DEA of the VRS type are a good way to measure the scale efficiency of the farm under study. Furthermore, the DEA method allows for the estimation of production frontiers in multi-product situations and for several inputs without imposing additional restrictions. Notwithstanding these major advantages of the non-parametric approach, several shortfalls have been documented in its use. Firstly, this approach does not take random variations into account, which could then influence the efficiency or inefficiency of a farm. Thus, the DEA method attributes all deviations in the production frontier to inefficiency. Secondly, the frontier function estimated through the DEA method does not provide any statistical properties that would allow for the testing of hypotheses. Finally, this frontier function is quite prone to extreme observations, which are largely responsible for the determination of this function (Amara et al, 2000; Coelli et al, 1998). Given these limitations, Coelli et al (1998), recommend the use of the DEA approach in sectors of activity whereby random effects are very low, the production of multi-products is high, the costs are difficult to quantify, and the behaviour of economic optimization such as cost reduction or maximization of profit are not the prioritized objectives in the sector under study. Presently, there are other non-parametric approaches which have statistical properties. For example, the m-efficiency approach (Cazals et al, 2002; Simar and Wilson, 2007, 2011) provide us with a more robust non-parametric approach, which is less sensitive to extreme values, to errors in measurement and to statistical noise (Cazals et al, 2002; Broekel, 2012). This new approach has been used in several studies, notably those of Broekel and Brenner (2007) and Broekel (2012).

The parametric approach proposes, on the other hand, an approximation of the production function by an *a priori* known functional form (Amara et al, 2000). Thus, an easier specification and a better analysis of the various algebraic properties of this function are possible. Several authors have refined the specification of this model by using the Cobb-Douglas functional form to estimate the frontier production function (Timmer, 1971; Richmond, 1974). This approach allows for the determination of a determinist frontier function shared by all the farms. In other words, that all farms share a common production mode and their respective performances are compared to that of this production frontier of cost and profit. All deviations that the farms demonstrate in relation to this frontier are wholesomely attributed to this inefficiency. The inconvenience is that this determinist and parametric approach neglects random factors such as climate variations that could affect the level of efficiency. Thus, currently the approach that uses the determinist functional form is less and less utilized and especially in regard to the agricultural domain, whereby hazards are diverse and in plenty. The specification currently used in the agricultural domain is the Stochastic Production Frontier because it takes into account hazards other than inefficiency (Aigner et al, 1977; Meeusen and Van den Broeck, 1977; Kumbhakar and Lovell, 2000; Coelli et al, 2005; Onumah et al, 2010). This approach assumes that the error term comprises the residual term that takes into account risks related to the random effects and a component that represents the inefficiency of the producer.

From the class of non-parametric methods, Caves et al (1982) introduce a calculation of the Malmquist index which measures changes in Total Factor

Productivity by distinguishing the changes in efficiency over the period of technical progress (Färe et al, 1989; FAO, 2017). It takes into account either the ratios of the distance of functions oriented towards outputs or the ratios of the distance of functions oriented towards inputs. Under various restrictions, the Malmquist index could easily be derived using the DEA approach as well as the stochastic approach (Odeck, 2007). Malmquist's productivity index has two major advantages. Firstly, no hypothesis can be made on the functional form of underlying production technology; and secondly, the data on the price of outputs and inputs is not mandatory. Nevertheless, it has the inconvenience of being sensitive to the chosen sample, the more the sample is restricted, the more the presence of inefficiencies and improbabilities (Coelli and Rao, 2001). Also, the calculation of this index assumes that observations will be undertaken over two periods (Odeck, 2007; Suresh, 2013).

Determinants of efficiency

Economics literature proposes two major approaches used to examine factors that influence sources of efficiency. These are the two-step estimation method, and the one-step simultaneous estimation method. The two-step approach requires, first, an estimation of the stochastic production function in order to determine efficiency scores, and thereafter regress the derived scores on explanatory variables (generally representing the specific characteristics of the farm and the farmer, and the institutional variables) using the Ordinary Least Squares (OLS), or Tobit regression methods. The major inconvenience of this two-step approach lies in the fact that, in the first place, the effects of inefficiency are assumed to be independent and similarly distributed so as to predict the values of efficiency scores. However, in the second phase, the efficiency scores thus obtained are assumed to depend upon a certain number of socioeconomic factors, which implies that the effects of inefficiency are not distributed in an identical manner, except if the coefficients of the considered factors are produced simultaneously. In order to overcome the limitations of the two-step approach, the one-step simultaneous estimation approach was introduced (Reifschneider and Stevenson, 1991; Battese and Coelli, 1995). In this model, the effects of inefficiency are expressed as an explicit function of a vector of explanatory variables, and all the parameters are estimated in a single step by using the maximum likelihood procedure. This single-step approach was used in several studies (Battese and Coelli, 1995; Amara and Romain, 2000; Kumbhakar and Lovell, 2000; Wang and Schmidt, 2002; Onumah et al, 2010; Njikam and Alhadji, 2017; Konja et al, 2019).

Several studies concerned with an analysis of the determinants of efficiency have been carried out in many parts of the world. These studies have demonstrated that efficiency is influenced by institutional, demographic and socioeconomic factors. Studies by Battese and Coelli (1995) and Balcombe et al (2008) have demonstrated that, generally, the determinants of efficiency in the agricultural sector are finance, agricultural extension services, the number of years of experience of the farmer, age, level of education, size of the farm, and mutual support, among others. Indeed, mutual support in agriculture allows for a reduction in costs and the constraints of manpower during the cultivation season. It thus leads to significant productivity gains (Boussard, 1987).

In Benin, Amoussouhoui et al (2012) used a stochastic frontier approach to estimate technical, allocative and economic efficiency of producers of seeds and rice at 0.72, 0.83 and 0.62, respectively. These results show that rice producers in Benin can still increase their level of technical efficiency by 28% and that of allocative efficiency by 17%. Experience in rice farming, the practice of agriculture as the main activity, and the percentage share of income from seeds in annual income, have a positive influence on technical efficiency of rice producers in Benin; whereas allocative efficiency is negatively affected by factors such as gender, the main activity (artisanal or trade), the use of previous crops and the number of visits by agricultural extension officers. Using the same stochastic frontier approach, Yabi (2009) evaluated the technical, allocative and economic efficiency of rice producers in Benin at 0.82, 0.85 and 0.70, respectively. The study also revealed that the factors that positively influence the efficiency of rice producers are: the level of education, belonging to a farmers' association, access to outreach services, the number of years of experience in rice growing, and access to finance. Adegbola et al (2006) demonstrates that in the Centre and the North of Benin, the most efficient rice growers were those who use animal traction, pesticides and improved seed varieties. Using the Cobb-Douglas production function, Kinkingninhoun-Medagbe et al (2010) estimates the technical efficiency of producers of irrigated rice in Benin at 0.84. Their study revealed that experience in rice growing, the date of rice planting and access to water are the factors that influence the technical efficiency of rice growers. Singbo and Lansink (2010) showed that there is at least 35% inefficiency in rice production in the lowlands of Benin. The determinants of inefficiency for these farmers are access to water, size of household, size of the farm and experience in rice growing.

The stochastic production frontier approach has also been used by Ouedraogo (2015) who estimated the technical, allocative and economic efficiency of rice producers in Burkina Faso at 0.80, 0.93 and 0.74, respectively. In this study, the age of the producer is the main source of inefficiency, with a positive relationship with technical inefficiency and a negative relationship with allocative inefficiency. In the analysis of the efficiency of rice growers in Ivory Coast, Nuama (2006) demonstrated that the main variables that influence the efficiency of rice growers are access to finance, access to leased land, the ownership of a cash crop growing farm and membership in a cooperative group. Omondi and Shikuku (2013), having analysed technical efficiency of rice growers in Ahero irrigation scheme in Kenya, found an efficiency score of 0.82. Variables such as sex, agricultural experience, level of income and distance from the market are the main factors that influence the technical efficiency of rice growers. Kadiri et al (2014) estimates the efficiency score of rice growers in the Niger Delta region of Nigeria at 0.63. They also identified the gender of the farmer and household size as being the key variables that influence technical efficiency. Heriqbaldi et al (2015) examined the determinants of technical efficiency in rice growers from 15 provinces of Indonesia. They concluded that the size of the farm and income are the variables which influence the technical efficiency of rice growers. In Nigeria, Akinbode et al (2011) estimated technical, allocative and economic efficiency at 0.72, 0.92 and 0.67, respectively. Furthermore, education, access to agricultural extension services and gender are the causes of technical inefficiency; whereas age, education, experience in rice growing, agricultural extension services and gender determine allocative efficiency. In order to determine the investment strategies that could improve rice production in Punjab in Pakistan, Kouser and Mushtaq (2007) utilized the Stochastic Production Frontier approach. The analysis of the results of the inefficiency model shows that investment in agricultural machines contributes to the improvement in technical efficiency of rice producers. Agricultural mechanization is therefore a sure means of increasing productivity in the area of rice production.

The non-parametric approach was used by Krasachat (2003) and Dhungana et al (2004) in order to measure the level of technical, allocative and economic efficiently in Thailand and Nepal, respectively. They identified the factors of inefficiency through the estimation of a Tobit model. Technical efficiency is estimated to be, on average, at 0.71 in Thailand (Krasachat, 2003) and the size of the farm is the key variable which affects the efficiency of producers. Dhungana et al (2004) estimated the indexes of technical, allocative and economic efficiency at 0.76, 0.87, and 0.66, respectively. They justified the difference in inefficiency between producers in Nepal by the difference in their use of resources such as fertilizer, seeds, manpower and agricultural equipment. Furthermore, the estimation of the Tobit model demonstrated that variables such as gender, level of education, attitude of the farmer in regard to risk and the availability of family labour are the factors which influence the efficiency of rice growers in Nepal; whereas allocative efficiency is determined by gender and the attitude in the face of risk.

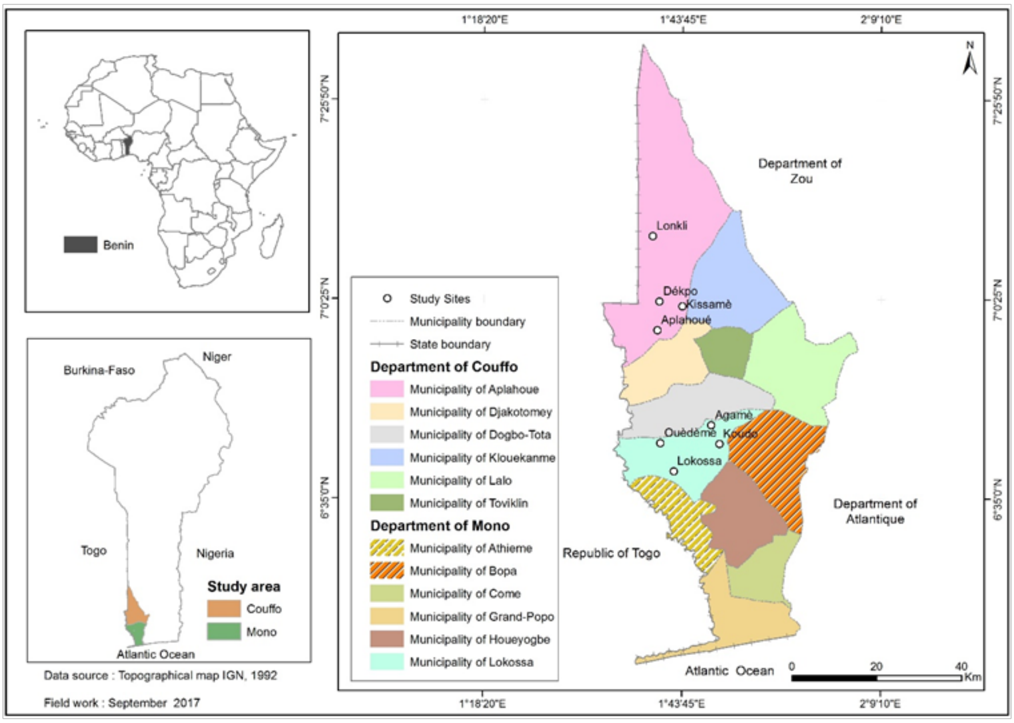
In summary, whichever the approach of measurement used (parametric or non-parametric) and whichever the functional form of the production function, the results lead us to believe that the level of efficiency is explained through socioeconomic and demographic factors. Gender, experience in rice production, access to credit and access to agricultural extension services are the variables that have been identified in most studies as the main factors which affect the efficiency of rice growers. In economics literature, there are very few studies that have undertaken a comparative analysis of efficiency scores and identified common factors which impact upon the efficiency of rice growers, focusing on two or more regions. This study will help to bridge this gap in literature by identifying common variables that influence efficiency in two departments of Benin.

3. Methodology of the study

Presentation of the zone under study and data sources

The study was undertaken in Benin, in the departments of Mono and Couffo (Figure 1). These departments are situated towards the South-West of the Republic of Benin. They are located between 6°15 and 7°30 latitude North and 2°10 longitude East, and are bordered to the north by the Zou department and to the south by the Atlantic ocean; to the west by the Republic of Togo, with a natural border; the River Mono which runs for 120 kilometres, and to the east by the Couffo valley, and Lac Ahémé which separates them from the departments of Atlantique and the Coast. Annual rainfall fluctuates at about 1,100mm, with four seasons, namely, the long rains season from March to July, a short dry season from August to September, a short rains season from September to November, and a long dry season from December to March. The departments of Mono and Couffo cover a surface area of 4,009 square kilometres, or 3.6% of the total land surface of Benin. The arable area is 2,550 square kilometres, or 62% of the total land mass.

Figure 1: Map of the zone under study



Source: Field Work, 2017

The departments of Mono and Couffo were chosen for this study because: (1) they are among the regions with the lowest levels of rice production in Benin, (2) they comprise vast agricultural lands and hold agro-ecological potential for the cultivation of rice. Indeed, these departments are endowed with 17,000 hectares of lowlands that are available for rice production. To this could be added 27,000 hectares of flood plains. Despite these potentialities, the departments are characterized by high levels of food insecurity and poverty (Table 1), and are classified among the three poorest departments in Benin (INSAE, 2015). The majority of the population is involved in subsistence farming and in other economic activities such as fishing, livestock, small businesses and crafts. The main crops grown in the two departments are maize, cassava, cowpeas/beans, rice, tomatoes, pepper, okra, vegetables, cotton and palm oil. Rice production in the departments of Mono and Couffo is relatively higher than the average in the country. However, the farms dedicated to rice production are smaller than those in other departments such as Alibori and Atacora. This situation could explain the rice deficit observed in the departments of Mono and Couffo.

Table 1: Socioeconomic characteristics of the departments of Mono and Couffo

	Mono	Couffo	Alibori	Atacora	Benin
Population (2013)	497,243	745,328	867,463	772,262	10,008,749
Rate of school enrolment	52.1	39.6	17.5	26	43.1
Main economic activity	Agriculture, fishing, livestock, small-scale business, trade and crafts	Agriculture, fishing, livestock, small-scale business, trade and crafts	Agriculture, fishing, livestock, small-scale business, trade and crafts	Agriculture, fishing, livestock, small-scale business, trade and crafts	Agriculture, fishing, livestock, small-scale business, construction, trade, agri-business, cement production and crafts
Main crop	Maize, cassava, cowpeas, rice, pepper, okra, vegetables, palm oil	Maize, cassava, cowpeas, rice, pepper, okra, vegetables, cotton	Maize, cassava, cowpeas, rice, cashews, cotton	Maize, cassava, cowpeas, rice, cashews, cotton	Maize, rice, beans, cassava, cotton, cocoa, pineapples, cashews, palm oil
Food insecurity (%)	35.3	44.5	60	45	34
Poverty rate (%)	43.5	46.6	36.3	39.7	36.2
Rice yields (kg/ha)	3347	3127	3820	2568	3031

Source: INSAE (2011, 2015).

This study uses secondary type data. It is derived from the 2013 database of the Ministry of Livestock and Fisheries. This is information that is taken from technical and economic data collected from farmers during the agricultural campaign of 2012-2013 in the departments of Mono and Couffo by the regional council of rice growers (CRR) with the support of the Support Project for the Agricultural Sector of Mono and Couffo (FAFA-MC) and of CARDER-Mono-Couffo. CARDER collects information on the rainfall in three different areas of each municipality, and these are compiled at the departmental level. Before collecting data, the regional council of rice growers of the departments of Mono and Couffo undertook a census of rice growers in 2011. This revealed the presence of 3,282 rice growers of whom 64% are from the department of Couffo and 36% from Mono. On the basis of this distribution of rice growers in the departments of Mono and Couffo, the technique of proportional sampling was used in order to obtain 210 growers. These regional surveys were developed in order to collect reliable information related to the socioeconomic characteristics of rice growers as well as the inputs used in rice production, so as to better understand agricultural practices and to give support to farmers in these regions.

Analytical models and variables used in the study

The technical efficiency model

The stochastic frontier model is used in this study. This approach was preferred to the DEA non-parametric method because it uses the maximum likelihood method which gives more robust results than the DEA method which relies on mathematical programming. Furthermore, contrary to the determinist approach, the interest in the stochastic approach is that it allows for the differentiation of inefficiency linked to growers from the random effects that cannot be controlled by the farmers (Aigner et al, 1977; Meeusen and Van den Broek, 1977; Kumbhakar and Lovell, 2000; Coelli et al, 2005; Onumah et al, 2010). It, therefore, allows for the taking into account of the stochastic nature of the agricultural sector. Also, the basic assumption of the non-parametric method and the determinist frontier according to which all the gaps relates to the frontier are due to inefficiency in farms is quite unrealistic in the agricultural sector because inefficiency in the sector can also be attributed to climatic risks, to phytopathology and to harmful insects, to government policies, international markers, etc. (Njeru, 2010).

Mathematically, the stochastic production function is represented as follows:

$$Y_i = f(X_i;\beta).\exp(\varepsilon_i) \quad (1)$$

$$Y_i = f(X_i;\beta).\exp(v_i).\exp(-u_i) \quad (2)$$

Whereby, Y_i is the production level of the rice grower *i, f* is the production frontier, X_i represents the vector of inputs, and β the vector of estimated parameters. ε_i is the error term composed of two independent elements v_i and u_i such that $\varepsilon_i = (v_i - u_i)$. v_i is the error term taking into account the factors (climate, pilferage, luck, topography, etc.) which are not in the control of the rice farmer. u_i is the non-negative error term that represents specific factors of the farmer and the farm and which contribute to the inefficiency of the rice grower. The hypotheses of the model are: (1) u_i is not negative and follows a semi-normal law of the average μ and of variance σ_u^2 following a normal distribution of average 0 and variance v_i; (2) σ_v^2 and v_i are independent between them and independent of explanatory variables. The interest variables in this model are $\sigma^2 = \sigma_\mu^2 + \sigma_\vartheta^2$ and $\gamma = \frac{\sigma_\mu^2}{\sigma^2}$. By definition, the parameter γ is comprised between 0 and 1. A value of y=1 indicates that the deviation of the frontier is entirely due to technical inefficiency, whereas a value y=0 signifies that all frontier deviation is due to random shocks. Thus if 0<γ<1, the production variation is characterized by the presence of both technical inefficiency and random shocks.

The estimation of the production function assumes that the limit of the production function is defined by the farmer engaging the best agricultural practices. This therefore indicates that the maximal potential production for a given set of inputs is given as:

$$y_i^* = f(X_i;\beta).\exp(v_i) \tag{3}$$

The measurement of technical efficiency (ET) of the rice grower *i* is defined as the relationship between the observed production and the potential production.

$$ET_i = \frac{y_i}{y_i^*} = \frac{f(X_i;\beta).\exp(v_i).\exp(-u_i)}{f(X_i;\beta).\exp(v_i)} = \exp(-u_i) \tag{4}$$

Equation 4 shows that the difference between observed production Y_i and that which is potential (y_i^*) is as a result of u_i. Thus if $u_i = 0$, then $y_i = y_i^*$. This implies that the production of farmer i is located on the production frontier and is therefore technically efficient. If $u_i > 0$, then $y_i < y_i^*$. This implies that the production of farmer *i* is located below the production frontier and is therefore technically inefficient.

A Cobb-Douglas production function is used in this study. This function has been chosen because of its flexibility (Bravo-Ureta and Evenson, 1994; Amegnaglo, 2020). Another advantage of the Cobb-Douglas production function is in the easy interpretation of returns to scale. This functional form is used in several studies, notably, Timmer (1971), Richmond (1994), Kinkingninhoun-Medagbe et al (2010), Ouedraogo (2015), Adedoyin et al (2016), Elias et al (2017), Amaechina and Eboh (2017) and Amegnaglo (2020).

The general form of the model is presented as follows:

$$\ln(Y_i) = \beta_0 + \sum_{j=1}^{9} \beta_j \ln X_{ij} + (v_i - u_i) \tag{5}$$

Whereby, Y_i is the quantity of rice produced per hectare; β the vector of estimated parameters; X_{ij} is the vector of inputes used by the producer *i*. It is comprised of the manpower (X_1) measured in terms of man per day per hectare; the proportion of hired labour (X_2); the quantity of local seeds (X_3) in kg/ha; the quantity of improved seeds (X_4); the quantity of fertilizer used in kg/ha (X_5); the quantity of pesticides used (X_6) in litres/ha; and of the quantity of rain water (X_7). We also add variables on the types of soil like clay soil (X_8), loam soil (X_9) and the use of irrigation (X_{10}). A binary variable for the seasons (X_{11}) was included to test the difference in the production frontier for the two seasons (long and short rains seasons).

The allocative efficiency model

According to studies by Khandaker et al (1993), Byinringiro and Reardon (1996), Chavas et al (2005), Ogundari (2008) and Ajoma et al (2016), allocative efficiency is determined based on the neoclassical production theory. Thus, there is allocative efficiency when a firm manages to make the marginal productivity of each input equal to its price. As farmers are price takers in the input market, the marginal cost of each input is equal to its price. This approach allows us to identify the production inputs that are used inefficiently. This information is useful for policies of the improvement of the use of agricultural inputs. In order to determine allocative efficiency, Average Physical Product (APP) and Marginal Physical Product (mPP) are calculated using the estimation of the Cobb-Douglas production function (Equation 6) using Ordinary Least Squares (OLS).

$$PPM = {}^{Y}/_{X_i} \quad \text{and} \qquad PPm = {}^{\partial Y}/_{\partial X_i} * PPM = \beta * PPM$$

Whereby, Y is the average production of rice per hectare, X_i is the average of inputs and β the estimated coefficients. The value of the marginal productivity (VPm) is calculated by multiplying the marginal physical product by the price of the output (Py). Allocative efficiency is given by Equation 6.

$$EA = {}^{VPm}/_{P_i} \tag{6}$$

Work includes the salary rate and the cost of food given to workers.

The inefficiency model

The inefficiency model of rice producers is defined in the following manner:

$$U_i = \delta_0 + \sum_{m=1}^{8} \delta_m Z_{mi} \tag{7}$$

Whereby, δ is the vector of estimated parameters; Z the vector of specific variables that are assumed to be the source of inefficiency for rice grower *i*. It is comprised of the age of the rice grower (Z_1) expressed in years; the sex of the rice grower (Z_2); the level of education (Z_3) which is a dummy variable with the value of 1 if the rice grower has at least a primary level of education and 0 if not; the total sown area (Z_4); the type of crop (Z_5) indicating whether the rice grower is cultivating for consumption or for seeds; the use or non-utilization of improved seeds (Z_6); access or lack of access to finance (Z_7); and finally a regional variable (Z_8) which takes into account the geographical situation of the rice grower.

The maximum likelihood method was used to estimate the production functions and the inefficiency factors of rice growers. The estimation was done in a one-step STATA calculation using the FRONTIER programme. The one-step estimation is preferred to the two-step methods or Tobit used in various studies (Krasachat, 2003; Dhungana et al, 2004; Konan et al, 2014) because the assumption given in the first step of estimation in two-steps, namely, that the inefficiency term was independently and identically distributed was not compatible with the quest for an eventual relationship with other socioeconomic variables which are operational in the second step (Amara and Romain, 2000; Kumbhakar and Lovell, 2000; Wang and Schmidt, 2002).

4. Results and interpretation

Descriptive analysis

The analysis of the descriptive statistics (Table 2) shows that, generally, men are more dedicated to rice cultivation than women. Indeed, women occupy a secondary position in all the decision making processes within the farm lands. Only 38% of the rice growers surveyed are educated. This could explain the low adoption of agricultural intensification practices by rice growers. Seed growing is practiced by 5% of the farmers surveyed. They ensure local availability of certified seeds. In regard to the planting season, 88% of the farmers plant during the long rains season. This shows that a majority of producers depend mostly on rain water because the long rains season has more precipitation. The amount of rain in the region varies between 831.4mm and 1,468.8mm with an average of 1,123.7mm. Rice growing is more prevalent in the department of Couffo as compared to that of Mono. Financial support received by the farmers surveyed comes from projects and programmes in place in these departments. Without guarantors, the farmers cannot directly access bank credit. Financial support is received from the project known as Support Facility for the Agricultural Sector of Mono-Couffo (FAFA-M/C). Only 11% of those surveyed have benefitted from this support. Among the farmers surveyed, 68% adopted improved rice varieties while the rest use traditional varieties.

The sown surface varies between 0.25 hectares and five hectares with an average of 1.7 hectares. The quantity of seeds per hectare is still quite varied. It spreads from 25kg to 100kg. However, the average, which is 64.5kg per hectare, tends to follow the norm which is 60kg. A significantly high proportion of farmers (73%) in the department of Couffo used fertilizer compared to those in Mono (39%). All the farmers still do not use inputs on their farms. The average quantity of fertilizer and pesticides per hectare at 78.1kg and 0.7L, respectively, are quite low. The agricultural board recommends the use of 150-250kg of fertilizer per hectare according to the type of crop grown. The production per hectare varies between 1,002.7kg and 4,533.3kg. Although yields from rice are improving among certain farmers, low yields are still observed for a majority of growers, which proves that there is still room for improvement of yields in the departments of Mono and Couffo. An analysis of the difference in yields reveals that there is no significant difference between the sexes. Higher yields are observed from farmers who use fertilizer, pesticides, improved seeds and those who have access to credit.

Table 2: Profile of respondents

Definition of variables		Combined	Mono	Couffo	t-test / Khi2
Age	**(Years)**	41.4	40.1	42.1	-1.12
Area Sown	(ha)	1.7	1.3	1.9	-3.85***
Quantity of seeds	(kg/ha)	64.5	59.2	67.4	-3.43***
Quantity of local seeds	(kg/ha)	21.86	23	21.23	0.37
Quantity of improved seeds	(kg/ha)	44.92	38.08	48.73	-2.14**
Quantity of fertiliser	(kg/ha)	78.1	45.4	97.4	-4.86***
Quantity of pesticide	(Litre/ha)	0.7	0.8	0.6	1.64
Labour	(Man-Day/ha)	258.3	281.9	245.3	1.65*
Proportion of hired manpower	(%)	39.8	35.1	42.5	-1.34
Yield	(kg /ha)	2536.1	2315.5	2658.6	-3.5***
Rainfall	(mm)	1123.7	983.1	1201.9	-12.62***
Irrigation	(Yes=1, No=0)	0.11	0.13	0.10	0.64
Gender	(Man=1, Woman=0)	0.68	0.7	0.67	0.08
Education	(Yes =1, No = 0)	0.38	0.48	0.32	5.35**
Type of crop	(Consumption=1, Seeds=0)	0.95	0.97	0.94	1.12
Improved variety	(Yes =1, No = 0)	0.68	0.68	0.67	0.007
Access to finance	(Yes=1, No=0)	0.11	0.12	0.1	0.13
Use of fertilizer	(Yes=1, No=0	0.60	38.6	0.73	24.34***
Use of pesticides	(Yes=1, No=0)	0.28	0.33	0.25	1.58
Clay soil	(Yes=1, No=0)	0.74	0.77	0.72	0.56
Loam soil	(Yes=1, No=0)	0.15	0.04	0.22	12.08***
Average price of fertilizer	FCFA/kg	248.94	242.6	252.47	-0.97
Average price of pesticide	FCFA/L	1397.97	1694.6	1233.14	1.39
Average price of seeds	FCFA/kg	349.38	353.52	347.38	0.77
Average price of manpower	FCFA	1845.79	1822.6	1858.63	-0.43

Note: ***, **, * represents confidence at 1%, 5% and 10%, respectively.

A comparative analysis of the profile of rice growers in the departments of Mono and Couffo shows that there is no significant difference in terms of age, gender, the type of crop grown, the use of improved seeds and access to finance. In regard to various agricultural variables, significant differences were observed. Rice producers in Couffo have higher yields than those in Mono. This significant difference shows how climatic conditions and the poor use of inputs affect rice production. Indeed, rice growers in the department of Couffo have larger farms and benefit from relatively better rainfall patterns (Table 2). They also use a higher amount of fertilizer compared to farmers in the department of Mono. No significant difference has been observed between the departments of Mono and Couffo in terms of the prices of production inputs.

Estimations of technical efficiency

Estimations of the stochastic production model and efficiency scores

Table 3 presents the results of estimations of the stochastic production model. The gamma coefficient is very close to 1 and is significantly different from zero. This implies the existence of technical inefficiency among rice growers in the departments of Mono and Couffo. The hypothesis of the absence of inefficiency is therefore rejected at the 1% confidence level.

Table 3: Estimation of the stochastic production model

Production variables	Coef	Prob
Percentage of hired labour	-0.008	0.826
	(0.038)	
Manpower	0.070***	0.000
	(0.019)	
Local seeds	0.072**	0.044
	(0.036)	
Improved seeds	0.191***	0.000
	(0.053)	
Fertilizer	0.085***	0.001
	(0.026)	
Pesticides	0.048**	0.043
	(0.024)	
Rainfall	0.527**	0.031
	(0.265)	
Clay soil	0.175***	0.007
	(0.065)	
Loam soil	0.115**	0.119
	(0.075)	
Irrigation	-0.008	0.804
	(0.036)	
Season	-0.042	0.382
	(0.048)	
Constant	-0.338**	0.068
	(0.173)	
Gamma	0.985***	0.002
Waldchi2(9)	79.11***	
Log likelihood	40.39	

Note: ***, **, * represents confidence at 1%, 5% and 10%, respectively. Value in parenthesis are robust standard errors.

The estimation results show that all the production variables included in the model, with the exception of irrigation and the season of cultivation, significantly contribute to the increase of yields of rice in the departments of Mono and Couffo. The lack of significance of the irrigation variable could be explained through the fact that a very small number of growers (11%) use irrigation techniques. Seeds contribute more to production per hectare than the other agricultural inputs under consideration. An increase by 1% of improved seeds would lead to an improvement by 19% of rice yields. The producers who used the largest quantities of improved seeds per hectare obtained the best yields. These results agree with those arrived at by Shabu (2013) and Oppong et al (2014) who demonstrated that seeds contribute to close to 25% in rice and maize production in Nigeria and Ghana, respectively. Pesticides and manpower are the inputs that contribute the least to rice production in the departments of Mono and Couffo. This highlights the importance of modernizing agriculture in Benin through high mechanization and the adoption of new technologies. These results are in agreement with those arrived at by Ogundari (2008) and Oppong et al (2014). However, Chirwa (2007) demonstrated that labour is the main contributor to production in Malawi, because production is more intensive. We also observed that the type of soil is an important factor in increasing rice production. Farmers who have clay soil have higher productivity as compared to those who have loam and sandy soil. Indeed, clay soils make water to stagnate, which leads to an increase in the productivity of water and rice (Tsubo et al, 2007).

The estimated technical efficiency varies between 42% and 99%, with an average of 78% (Table 4). Almost 7% of producers have a level of technical efficiency that is lower than 50%. The results suggest that there are possibilities of increasing rice production in the short term through adopting the best agricultural practices. These results are similar to those obtained previously by Krasachat (2003), Dhungana et al (2004), Adegbola et al (2006), Yabi (2009), Kinkingninhoun-Medagbe et al (2010), Singbo and Lansink (2010), Kadiri et al (2014), Konan et al, (2014), and Ouedraogo (2015) who demonstrated that there are possibilities of increasing rice production. Rice growers would therefore benefit greatly from improving the use of production resources.

Table 4: Distribution of technical efficiency scores and yields

Efficiency \ Yields	1000-2000	2001-2500	2501-3000	3001-4000	4001-5000	Total
0.42-0.5	14	0	0	0	0	14
0.51-0.6	21	2	0	0	0	23
0.61-0.7	9	15	2	0	0	26
0.71-0.8	2	17	12	1	0	32
0.81-0.99	0	10	59	42	4	115
Total	46	44	73	43	4	210

A cross-sectional analysis of the efficiency scores with the production yields reveals that 50% of the producers have a level of efficiency that is higher than 80% and yields that are higher than 2,500kg/ha. There is therefore a high positive correlation (r =0.90) between the efficiency level and the yields of the producer. Thus, the highest levels of efficiency are associated with the highest yields. This implies that the most efficient producers have the best yields. An improvement of the level of efficiency would therefore lead to an increase in yields by the producer.

Determinants of technical efficiency

Table 5 presents the results of the model of technical efficiency. Overall, the variables which affect technical inefficiency (model 1) are age, sex, education and access to finance. The Chow test (P-Value >F (8.194=0.0032) applied to this model indicates that the determinants of technical efficiency are different in the two regions under study (models 2 and 3). The coefficient of age is positive and significant.[1] This implies that the older rice growers are less efficient than the younger ones who are more receptive to technical changes in production which influences efficiency (Singbo and Lansink, 2010; Khan and Ali, 2013; Oppong et al, 2014). The coefficient of the sex variable is estimated to be positive. This suggests that male farmers are less efficient than female farmers. This is probably due to the fact that women generally do not have access to production resources (Amegnaglo, 2020); farmers are forced to allocate resources more effectively. The coefficient associated with the education variable is negative and significant. This suggests that the level of education of rice growers contributes to the reduction of inefficiency in rice production. This result confirms previous studies (Battese et al, 1996; Yabi, 2009; Elias et al, 2017) which showed the positive relationship between technical efficiency of producers.

Table 5: Results of the estimation of a model of technical inefficiency

Variables of technical inefficiency	(1) Combined	(2) Mono	(3) Couffo
Age	0.028***	-	0.029**
	(0.010)		(0.012)
Gender	0.500*	0.52	0.499*
	(0.258)	(0.540)	(0.275)
Education	-0.747***	-1.59*	-0.047*
	(0.289)	(0.825)	(0.026)
Area sown with rice	-0.143	-0.07	0.532***
	(0.095)	(0.146)	(0.038)
Type of crop	-0.489	1.47	-0.558
	(0.614)	(2.796)	(0.555)
Use of improved varieties	-0.312	-1.22*	0.040
	(0.313)	(0.603)	(0.299)
Access to finance	-3.116**	-0.82	-1.271***
	(1.527)	(1.240)	(0.385)
Location	-0.421	-	-
	(0.304)		
Constant	-2.273***	-2.83	-2.379***
	(0.898)	(3.120)	(0.897)
Chow Test [K, N-2*K] = 3,0195	P-Value > F(8 , 194) = 0,0032		

Note: ***, **, * represents confidence at 1%, 5% and 10%, respectively. Value in parenthesis are robust standard errors.

Access to credit presents a negative and significant coefficient, therefore suggesting that accessibility of credit allows for the reduction of inefficiency of rice growers in the departments of Mono and Couffo. Several studies (Nuama, 2006; Yabi, 2009; Oppong et al, 2014; Elias et al, 2017) showed that access to finance is a positive factor in increasing the efficiency of producers because rice growers would stock up on agricultural inputs in real time and avoid the eventual delay of production activities (Bjornlund and Pittock, 2017; Mdemu et al, 2017; Nonvide et al, 2018).

Estimation of determinants of allocative efficiency

Estimation of allocative efficiency

Table 6 shows the value of marginal productivity of each input of scores of allocative efficiency. The comparison test (t-test) between two regions (Mono and Couffo) indicated an absence of significant differences in terms of manpower (t = -0.46), of seeds (t = -0.007), fertilizer (t = -1.16), and pesticides (t = -0.52). An analysis of the results shows that none of the production inputs is used in an efficient manner in the departments of Mono and Couffo.

Table 6: Allocative efficiency of production inputs

Variable	APP			MPP			VMP			AE =VMP/P		
	Combined	Couffo	Mono	Combined	Couffo	Mono	Combined	Couffo	Mono	Combined	Couffo	Mono
Manpower	14.17	14.57	13.45	1.04	1.07	0.99	157.38	161.82	149.39	0.08	0.08	0.07
Seeds	40.93	39.92	42.76	5.64	5.50	5.90	847.39	826.38	885.198	2.49	2.49	2.49
Fertilizer	15.83	19.85	8.60	1.56	1.96	0.85	235.16	294.78	127.85	1.58	1.64	1.36
Pesticides	379.27	355.13	422.72	18.58	17.40	20.71	2787.65	2610.22	3107.01	2.21	2.31	2.06

Note: APP=Average Physical Productivity, MPP= Marginal Physical Productivity, VMP= Value of Marginal Productivity, AE= Allocative Efficiency, and Pi the price of input i.

The coefficient of allocative efficiency of manpower (0.08) is lower than 1. This is an indication that the manpower production factor is over-utilized in the departments of Mono and Couffo. There is therefore inefficiency in the use of manpower in the departments of Mono and Couffo. None of the rice growers use manpower efficiently. A reduction of manpower allows for an increase in profits of the producer. This result confirms those obtained previously by Ogundari (2008).

The allocative efficiency of seeds was estimated at 2.49, which is superior to 1. These results indicate that the seeds input is underutilized in the production of rice in the departments of Mono and Couffo in Benin. Thus, the rice growers will benefit from increasing the quantity of seeds used. Similar results have been obtained by Ogundari (2008), Ajoma et al (2016) and Amaechina and Eboh (2017) which demonstrates a sub-optimality in the use of seeds by producers. The coefficients of allocative efficiency of fertilizer and of pesticides are 1.58 and 2.21, respectively. We could therefore state that fertilizer and pesticides are underutilized in rice production in the departments of Mono and Couffo in Benin. This could be explained through the fact that a majority of producers do not apply the recommended norms for the use of fertilizer and pesticides because of the high cost of inputs. For example, 83% of the rice producers in the two departments use quantities of fertilizer that are lower than the recommended rate which is 150-250kg/ha. These results are in agreement with those arrived at by Ajoma et al (2016) and Amaechina and Eboh (2017). Rice producers in the departments of Mono and Couffo would greatly benefit from an increase in the quantity of fertilizer and pesticides used.

Determinants of allocative efficiency

Table 7 presents the results of determinants of allocative efficiency. Overall, variables which affect technical inefficiency (model 1) are age, gender, sown area, the type of crop and access to credit. The Chow test (P-Value >F (8.194)= 0.0044 reveals that the determinants are different in regard to the two regions of the study. This is confirmed through the fact that variables are not significant in the two regions (models 2 and 3).

Age is a negative and significant coefficient. This suggests that the younger rice growers allocate their resources more effectively than the older ones. This could be explained through the fact that youth have unlimited access to resources. These results agree with those obtained by Akinbode et al (2011) and Ouedraogo (2015) who demonstrate that age is a factor of allocative efficiency, and that younger people have a better allocation of resources as compared to their elders. The coefficient of the gender variable is also negative and significant, indicating that women are less efficient than men. This result is the same as that arrived at in previous studies (Dhungana et al, 2004; Akinbode et al, 2011; Amoussouhoui et al, 2012) showing that allocative efficiency is negatively affected by the gender of the producer.

Table 7: Determinants of allocative efficiency

Variables of allocative efficiency	(1) Combined	(2) Mono	(3) Couffo
Age	-0.009***	0.010*	0.013***
	(0.003)	(0.006)	(0.004)
Gender	-0.171**	- 0.298*	- 0.005
	(0.081)	(0.178)	(0.102)
Education	0.105	0.018**	0.106
	(0.078)	(0.009)	(0.100)
Area sown with rice	0.041***	0.032	0.037***
	(0.002)	(0.057)	(0.002)
Type of crop	0.454***	0.065	0.502***
	(0.129)	(0.163)	(0.153)
Use of improved varieties	0.080	0.428***	-0.174
	(0.093)	(0.158)	(0.129)
Access to finance	0.566***	0.409**	0.722***
	(0.115)	(0.271)	(0.136)
Location	0.107	-	-
	(0.081)		
Constant	1.172***	1.527***	1.455***
	(0.256)	(0.364)	(0.336)
Chow Test [K, N-2*K] = 2.9050	P-Value > F(8 , 194) = 0,0044		

Note: ***, **, * represents confidence at 1%, 5% and 10%, respectively.

The positive relationship observed between the sown area and the allocative efficiency shows that producers cultivating a larger surface area allocate their resources better, according to size. Thus they could benefit from economies of scale. The results also indicate a positive coefficient for the type of seed variable. This therefore suggests that growers of rice for the purpose of consumption have more allocative efficiency than those simply producing seeds. Indeed, seeds are sold at double the price of rice aimed at consumption thus seed growers invest more means in order to obtain the necessary yields. They can, therefore, purchase more expensive but available inputs that they assume are more effective as long as they do not impact upon the profitability of their production. We also observe the positive relationship between access to finance and allocative efficiency. Accessing financial resources in good time allows the farmer to acquire production factors in the shortest time possible (Bjornlund and Pittock, 2017; Mdemu et al, 2107; Nonvide et al, 2018).

Discussion

Table 8 gives a summary of previous studies undertaken in Benin. These studies cover different regions in the country. Some authors (Singbo and Lansink, 2010; Amoussouhoui, 2012) have used the two-step approach, whereas others (Yabi, 2009; Kinkingninhoun-Medagbe et al, 2010; Zannou et al, 2018) have used a one-step estimation of the stochastic production frontier. Our study completes previous studies, and covers the departments of Mono and Couffo, which are some of the weakest regions in terms of rice production in Benin. Contrary to previous studies, we applied the neoclassical production theory in order to determine the production inputs which are used efficiently. This element is important in terms of our study's contribution on efficiency in Benin. We observed that none of the production variables are used in an efficient manner. Manpower is over-utilized, whereas seeds, fertilizer and pesticides are underutilized.

The mean score of technical efficiency is estimated at 78% for rice growers in these departments. This result lies within the range of efficiency scores (65-92%) given in other studies (Yabi, 2009; Kinkingninhoun-Medagbe et al, 2010; Singbo and Lansink, 2010) on Benin, and is in agreement with results from other countries (Krasachat, 2003; Dhungana et al, 2004; Kadiri et al, 2014; Konan et al, 2014; Ouedraogo, 2015). The average estimated efficiency is 0.80 for rice producers in Burkina Faso (Ouedraogo, 2015), at 0.72 in Nigeria (Akinbode et al, 2011), and at 0.76 in Nepal (Dhungana et al, 2004).

Our results demonstrate that there is a potential for an increase in rice production in the departments of Mono and Couffo. Better resource allocation for production would allow rice producers in the departments of Mono and Couffo to achieve economies of scale. In order to do so, solid institutional support measures are required. According to our results, two key strategic variables are education and finance. The Oaxaca-Blinder decomposition test has shown that, if illiterate producers were to be educated, their technical efficiency would improve by 4.2%, and also if they have the same characteristics, this would improve their technical efficiency score by 9.5% (see Appendix 3). Equally, if producers without access to finance receive credit, their technical efficiency score would increase by 2.8%. Furthermore, they have the same characteristics as those who have access to finance, which could increase their technical and allocative efficiency by 9.6% and 52.6%, respectively (see Appendix 3). Improving farmers' education on good agricultural practices therefore allows farmers to increase the management practices in crop growing and their own efficiency, and thus increasing rice production. Several studies (for example, Oppong et al, 2014; Elias et al, 2017) have demonstrated that access to credit is an important factor for increasing the efficiency of producers. With finance, farmers could secure their agricultural inputs in time in order to avoid delays in their agricultural activities (Bjornlund and Pittock, 2017).

Table 8: Summary of results from previous studies in Benin

Authors	Area of study	Type of data	Methodology	Efficiency score	Sources of inefficiency
Zannou et al (2018)	Koussin-Lélé (Zou department)	Primary data from rice growers	One-Step Cobb-Douglas stochastic frontier approach	92%	- Production of rice as the main activity (-) - Education (-) - Contact with agricultural extension officers (-)
Amoussouhoui (2012)	South of Benin	Primary data	Stochastic production frontier approach and Tobit model	72 %	- Gender (-) - Experience in rice growing (-) - Frequency of visits by officers (-) - Percentage share of agricultural income (-) - Size of farm (-) - Geographic location (-)
Singbo and Lansink (2010)	Dassa Community (Collines department)	Primary data	Two-step approach: (1) Directional distance function, (2) Bootstrap truncated model	65 %	- Knowledge of use of water (-) - Married (-) - Formal education (-) - Family labour (-) - Experience (-) - System used in rice growing (+) - Integrated production Knowledge of use of water (+) - Age (+)
Kinkingninhoun-Medagbe et al (2010)	Koussin-Lélé (Zou department)	Primary data from rice growers	Two-step estimation of the stochastic frontier function	84%	- Experience (-) - Level of irrigation (-) - Date of planting (+)
Yabi (2009)	Gogounou Community (Alibori department)	Primary data from rice growers	One-step estimation of the stochastic production function and price	82 %	- Education (-) - Membership in an association (-) - Contact with agricultural extension agents (-) - Experience in rice growing (-) - Access to finance (-)

5. Conclusion

The objective of this study is to estimate technical and allocative efficiency and to identify the sources of inefficiency of rice producers in the departments of Mono and Couffo in Benin. The study uses a stochastic frontier approach in order to examine technical efficiency and the marginal value approach in order to examine allocative efficiency. Several conclusions could be drawn from this study: (1) Technical efficiency of rice growers is estimated at 78%; (2) Rice growers over-utilize manpower, and underutilize other production factors such as seeds, fertilizer and pesticides; and (3) The sources of inefficiency are age, gender, level of education and access to finance by the rice grower. These results suggest that there is still room to improve the production of rice in the departments of Mono and Couffo. Thus, it is necessary to conduct periodic trainings for rice growers on best practices in production. Outreach services could play an important role in this sense. The improvement of the efficiency of producers is also achieved through the use of agricultural technologies. It is, therefore, important to facilitate access to technology for rice growers. The efforts by the government and organizations that are involved in the sector should also be geared towards the promotion of agricultural finance. Access to finance is a key factor of development in the agricultural sector.

Notes

1. The variable “age” was removed from the regression for Mono department because of multicollinearity. However, when we introduce age squared into the collective model, the age variable stops being significant. See Appendix 2.

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Appendixes

Appendix 1: Definition of variables

Variables	Definition	Modalities	Unit
Age	Age of grower	Number	(Years)
Sown area	Total area cultivated by the rice grower	Number	(ha)
Quantity of seeds	Total quantity of seeds used for the growing of rice	Number	(kg/ha)
Quantity of local seeds	The quantity of local seeds used for the growing of rice	Number	(kg/ha)
Quantity of improved seeds	The quantity of improved seeds used for the growing of rice	Number	(kg/ha)
Quantity of fertilizer	Quantity of fertilizer used	Number	(kg/ha)
Quantity of pesticide	Quantity of pesticide used	Number	(Litre/ha)
Manpower	Quantity of manpower used	Number	(Men-Day/ha)
Percentage of hired labour	Percentage of hired labour on the farm	Number	(%)
Yields	Production achieved by the rice grower per unit of sown land	Number	(kg/ha)
Rainfall	Total quantity of rain in the production zone over a period of one year	Number	(mm)
Gender	Gender of farmer	(Man= 1, Woman= 0)	-
Education	Is the farmer educated?	(Yes=1, No=0)	-
Type of crop	Purpose of crop: consumption or seeds?	Consumption=1, Seed= 0	-
Season	Period of rice production (long rains or short rains season)	(Long=1, Short=0)	-
Irrigation	Deduced by whether or not the farmer owns a motor pump; or the undertaking of basic installations or not	(Yes=1, No=0)	-
Location	Department where the rice grower is located (Mono or Couffo)	(Couffo = 1, Mono =0)	-

continued next page

Appendix 1 Continued

Variables	Definition	Modalities	Unit
Improved variety	Use or non-use of improved varieties	(Yes=1, No=0)	-
Access to finance	Financial assistance given or not given to the farmer: Status	(Yes=1, No=0).	-
Use of fertilizer	Use of no fertilizer	(Yes=1, No=0).	-
Use of pesticide	Use of no pesticide	(Yes=1, No=0)	-
Clay soil	Type of soil clay or not	(Yes=1, No=0).	-
Loam soil	Type of soil loam or not	(Yes=1, No=0).	-

Appendix 2: Result of the inefficiency model integrating the square of the age

Variables of technical inefficiency	Coef	Prob
Age	0.069	0.288
Age squared	-0.0004	0.518
Gender	0.518*	0.088
Education	-0.806***	0.007
Area of rice sown	-0.124	0.355
Type of crop	-0.504	0.383
Use of improved varieties	-0.297	0.344
Access to finance	-3.353**	0.037
Location	-0.438	0.135
Constant	-3.156**	0.053

Note: ***, **, * represents confidence at 1%, 5% and 10%, respectively.

Appendix 3: Results of the Oaxaca-Blinder decomposition test

Blinder-Oaxaca decomposition Number of obs = 210

1: educ = 0
2: educ = 1

TEE	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Differential						
Prediction_1	.7306692	.0147727	49.46	0.000	.7017151	.7596232
Prediction_2	.8441256	.0144102	58.58	0.000	.8158821	.8723691
Difference	-.1134565	.0206371	-5.50	0.000	-.1539044	-.0730086
Decomposition						
Endowments	-.0428637	.018834	-2.28	0.023	-.0797777	-.0059498
Coefficients	-.0956212	.0257789	-3.71	0.000	-.1461468	-.0450956
Interaction	.0250285	.0273446	0.92	0.360	-.028566	.0786229

Blinder-Oaxaca decomposition Number of obs = 210

1: credit = 0
2: credit = 1

TEE	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Differential						
Prediction_1	.7464476	.0120564	61.91	0.000	.7228175	.7700777
Prediction_2	.9279617	.0076747	120.91	0.000	.9129196	.9430038
Difference	-.1815142	.0142919	-12.70	0.000	-.2095257	-.1535026
Decomposition						
Endowments	-.0287045	.0096326	-2.98	0.003	-.047584	-.0098251
Coefficients	-.0961464	.0300397	-3.20	0.001	-.1550231	-.0372698
Interaction	-.0566632	.0290099	-1.95	0.051	-.1135216	.0001952

Appendix 4: Results of the estimation of the technical inefficiency model through the Tobit method

Variables of technical inefficiency	Coefficient	Probability
Age	0.003	0.001
Gender	0.561	0.020
Education	-0.115	0.00
Area sown with rice	0.000	0.89
Type of crop	0.002	0.95
Use of improved varieties	0.019	0.383
Access to finance	-0.096	0.002
Location	-0.034	0.107
Constant	0.182	0.011

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