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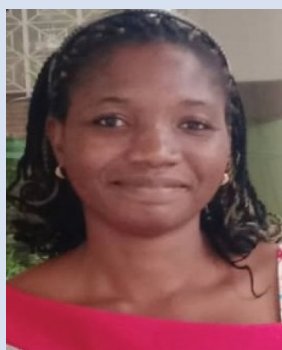
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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Estimation and determinants of efficiency among rice farmers in Benin

Véronique Houngue¹ and Gbêtondji Melaine Armel Nonvide^{1*}

Abstract: Rice plays an important role in achieving food security in Benin but its production remains low and needs to be optimized. This study estimates technical and allocative efficiencies as well as the sources of inefficiency among rice producers in Benin. The data used cover 210 rice producers, proportionally distributed in the Departments of Mono and Couffo. This farm-level data were collected under the project “Facilité d’Appui aux Filières Agricole du Mono et du Couffo (FAFA-MC).” We employed a stochastic frontier approach to analyze technical efficiency and the marginal value product approach for allocative efficiency analysis. Furthermore, a Chow test was performed to test for difference in determinants of efficiency between the two departments. We found that the average technical efficiency score of rice producers is 78%. The sources of technical inefficiency were age, gender, education level and access to credit. The results also revealed allocative inefficiency in rice production. Labour was overused while other inputs such as seeds, herbicide, and fertilizer were underutilized. Allocation efficiency was influenced by age, gender, area planted, type of culture, and access to credit. Finally, we found difference in determinants of efficiency between the departments of Mono and Couffo. Our results imply that there are opportunities to increase rice production in the Departments of Mono and Couffo. Rice producers in these departments therefore would benefit by adopting better farming practices such as the use of fertilizers, agrochemicals, and irrigation facilities.



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PUBLIC INTEREST STATEMENT

In Benin, rice is the second most consumed staple food crops after maize. However, rice yield has been decreasing since 2011 and there is still a significant gap between actual and potential yield. As consequence, national rice production is not sufficient to meet domestic demand for rice. This calls for policy interventions to increase rice farm efficiency and productivity. This study revealed that there are still opportunities to increase rice production efficiency. Labour is overused while other inputs such as seeds, herbicide, and fertilizer are underutilized in the country. The key policy variables that increase rice farm efficiency include education and access to credit. Improving farmers’ education on good agricultural practices would enable farmers to increase crop management practices and efficiency, and hence rice production. Also, promoting access to credit would help farmers to secure farm inputs on time and avoid delays in agricultural activities.

| **Keywords:** efficiency; rice production; mono; couffo; Benin

1. Introduction

Rice was introduced in Benin during the colonial era but its production began after the independence in the 1960s with the development of rice schemes by the State. Benin's population has been increasing at a rate of 2.9% from 1979 to 1992, 3.2% from 1992 to 2002, and 3.5% from 2002 to 2013 (INSAE, 2013). Domestic rice consumption increased from 7,000 tonnes in 1960 to 265,000 tonnes in 2010 and further increased to 729,000 tonnes in 2017 (USDA, 2018). The demand for rice was higher than local production. National Strategy for the Development of Rice Production (SNDR) in 2011 reported a low per capita consumption of about 3 to 4 kg in 1960's and it gradually increased to 12 kg in 2004 and between 25 and 30 kg in 2011. Per capita consumption of about 45.7 kg was reported in 2017 (PSDSA, 2017). Despite increases in domestic rice production (USDA, 2018), this is still not enough to meet the local demand. Domestic rice production actually covers only 25% of rice consumption (USDA, 2018). The consumption gap is then filled by imports (including the share of re-export) mainly from Asian countries (India, China, Thailand among others), which rose from 6,000 tonnes in 1960 to 195,000 tonnes in 2010 and 650,000 tonnes in 2018 (USDA, 2018). Rice import bill was estimated at 293 USD million in 2018 (USDA, 2018).

Rice has maintained its position as one of the promising commercial crop for economic growth, food security and poverty alleviation (PSDSA, 2017). It is one of the food crops the Government of Benin is focusing on to ensure food security and poverty alleviation in order to achieve the Sustainable Development Goals (SDGs). The objective of the rice policy in Benin is to increase rice production from 72,960 tonnes in 2007 to 600,000 tonnes (equivalent to 385,000 tonnes of milled rice) by 2015 to ensure self-sufficiency in rice production and generate surpluses for trade by 2018. However, the paddy rice production in Benin was estimated at 234,145 tonnes in 2015, which is far below the projected target of 600,000 tonnes by 2015. Rice yield has been low (3 tonnes per hectare) since 2003 while the yield potential of about 4–10 tonnes per hectare can be achieved depending on the varieties and production systems (MAEP, 2009).

Rice cultivation was introduced in the departments of Mono and Couffo (study area) in 1976. Its production is largely dominated by smallholder farmers. Alongside this, there are irrigated areas with partial or full control of water. However, rice is mostly produced in the lowland (improved or not). Rice production has not increased too much in the region, despite the possibility of turning it into a large-scale crop given the abundance of water resources. The analysis of achievement of rice acreage in the departments of Benin shows that the departments of Mono-Couffo recorded the weakest performance. The production in these departments was estimated at 3026 tonnes in 2015 compared to 6032 tonnes in 2014 and 971 tonnes in 2001 (MAEP, 2018). In the large rice-producing departments such as Atacora, Alibori and Collines, rice production in 2017 was estimated at 143 507 tonnes, 130,193 tonnes, and 49 456 tonnes, respectively (MAEP, 2018). The various interventions of the "Programme d'Urgence d'Appui à la Sécurité Alimentaire (PUASA)" and the "Société Nationale pour la Promotion Agricole (SONAPRA)" in the departments of Mono and Couffo have contributed to the increase in the total area planted from 316 ha in 2001 to 1101 ha in 2015 (MAEP, 2018), but the level of production remains low. The food balance sheet in the departments of Mono-Couffo revealed deficit in rice about 5,932 tons for Mono and 7,336 tons for Couffo in 2017. This deficit is chronic and intensifies the vulnerability of poor households through serious problems of malnutrition and stunting among children.

To reduce Benin dependency on imports and allow rice production to effectively contribute to food security and poverty reduction, it is imperative to optimize rice production systems by improving the productivity of production factors. Furthermore, as agricultural land cannot be increased indefinitely, there is a need for improvements in the efficiency of existing production factors in order to foster rice production. Hence, the study aims to provide answers to the following questions: What are the levels of technical and allocative efficiency of rice producers?

What are the determinants of inefficiency among rice producers? The overall objective of the study is to identify factors affecting technical and allocative efficiency among rice producers in Benin. Specifically, the study aims to: (1) estimate the scores of technical and allocative efficiency among rice farmers, (2) identify the determinants of the efficiency of rice producers in Benin, and (3) study whether the models of technical and allocative efficiency are the same in the two regions (Mono and Couffo).

Our study adds knowledge to the literature. First, it provides support for future policy interventions that promote the development of rice production. This comes at an important time, since national rice production remains insufficient to meet the domestic needs of the populations. Second, none of the previous studies (Amoussouhoui et al., 2012; Kinkingninhoun-Medagbe et al., 2010; Singbo & Lansink, 2010; Yabi, 2009; Zannou et al., 2018) on the efficiency of rice farmers in Benin was conducted in the departments of Mono and Couffo. Third, empirically most studies have not taken into account the issue of regional heterogeneity. In terms of methodology, we provide a rigorous estimation by using a one-step stochastic frontier approach to estimate technical efficiency, and a marginal value product approach to measure allocative efficiency. We also performed a Chow test to see whether the determinants of efficiency are the same between the two departments.

The rest of the paper is organized as follows. In Section 2, we present a literature review, followed by the materials and methods in Section 3, and in Section 4 we present the empirical results. The results are discussed in Section 5 and finally we conclude in Section 6.

2. Literature review

Parametric and non-parametric approaches are generally used in measuring technical efficiency. If the production function can be properly represented by a function with explicit parameters such as the Cobb-Douglas function or the trans-log function, the approach used is called a parametric. However, if the production function does not have a well-defined functional form, the approach is referred to as non-parametric. Therefore, the distinction between these approaches relates to the shape of the production function (Amara & Romain, 2000; Coelli et al., 1998).

The non-parametric approach (Amara & Romain, 2000; Coelli et al., 1998; Farrell, 1957) assumes that the production frontier does not require any functional form. It uses data envelopment (DEA) method of analysis introduced by Charnes et al. (1978). The DEA approach allows the estimation of production frontiers in multi-produced situations and for several inputs without imposing additional restrictions. Despite its major advantages, several criticisms have been made against the use of the non-parametric approach. Firstly, the non-parametric approach does not take into account the random variation that could influence the efficiency of the farm and assigns any deviation from the production frontier to inefficiency. Secondly, the production function estimated by the DEA approach has no statistical property to test the hypotheses. Finally, the production frontier is very sensitive to extreme observation, which is largely responsible for determining the frontier (Amara & Romain, 2000; Coelli et al., 1998). Given these limitations, Coelli et al. (1998) recommended the use of DEA approach in sectors where: random effects are very low, production of multi-products is important, prices are difficult to quantify, and economic optimization behaviors such as cost minimization or profit maximization are not the priorities of the sector. Nowadays, there exist other non-parametric approaches that allow for statistical properties to be calculated. For instance, the m-efficiency approach (Cazals et al., 2002; Simar & Wilson, 2007, 2011) provides a more robust non-parametric approach which is less sensitive to extreme values, measurement error, and statistical noise (Broekel, 2012; Cazals et al., 2002). This approach has been used in several studies including Broekel and Brenner (2007) and Broekel (2012).

From the class of nonparametric methods, Caves et al. (1982) introduced the calculation of the Malmquist index which measures the change in total factor productivity by distinguishing the change in efficiency over time from technical progress (FAO, 2017; Färe et al., 1989). It takes into

account either the output-oriented distance function ratios or the input-oriented distance function ratios. Under certain restrictions, the Malmquist index can be easily derived using the DEA approach as the stochastic one (Odeck, 2007). The Malmquist index has two main advantages. First, no assumptions are made about the functional form of the underlying production technology; and second, data on exit and entry prices are not essential. However, it has the disadvantage of being sensitive to the sample chosen, the smaller the sample, the more unlikely the appearance of inefficiencies (Coelli & Rao, 2001). Also, the calculation of this index requires observations over two (02) periods (Odeck, 2007; Suresh, 2013).

The parametric approach proposes the specification of the production function by a priori known functional form (Amara & Romain, 2000). Thus, a better analysis of different statistical properties of this function is possible. Several authors have refined the specification of this model using the Cobb-Douglas functional form to estimate a production frontier (Timmer, 1971; Richmond 1974). This approach allows the estimation of a deterministic frontier shared by all the farms and their performances are compared to the production frontier, cost, or profit. Any difference between the production function of the farm and the frontier is totally attributed to inefficiency. The downside is that the deterministic approach neglects the random factors such as extreme weather, pests, and international markets, among others, which can affect the level of efficiency; this makes the deterministic frontier method (as opposed to stochastic) less used especially in agriculture where hazards are many and diverse. The stochastic production frontier specification is therefore commonly used in agriculture (Aigner et al., 1977; Coelli et al., 2005; Kumbhakar & Lovell, 2000; Meeusen & Van den Broeck, 1977; Onumah et al., 2010) because it includes the random factors. The stochastic production frontier assumes that the error term consists of a residual term comprising the risks associated with random effects and a component representing the inefficiency of the producer.

Several empirical studies on efficiency analysis were performed within agricultural sector worldwide. The works of Battese and Coelli (1995) and Balcombe et al. (2008) have shown that generally, the determinants of efficiency in agriculture are age, farming experience, education, farm size, access to extension services and credit, and mutual assistance among others. Indeed, mutual assistance in agriculture allows reduction of costs and stress for labor during the growing season, and therefore leads to gains in productivity (Balcombe et al., 2008; Boussard, 1987). In Benin, Amoussouhoui et al. (2012) used a stochastic frontier approach to estimate technical, allocative, and economic efficiency of rice producer at 0.72; 0.83, and 0.62, respectively. These results show that rice farmers in Benin can still increase their level of technical efficiency by 28% and allocative efficiency by 17%. Experience in rice production, having agriculture as main activity and share of income from rice production in annual income have a positive influence on the technical efficiency of rice farmers in Benin. While the allocative efficiency is negatively affected by factors such as gender, having crafts and commerce as the main activity, the use of crop residues and the number of visits by extension agents. Using the same approach of stochastic frontier, Yabi (2009) evaluated the technical, allocative, and economic efficiency of rice farmers in Benin at 0.82, 0.85, and 0.70, respectively. The study also revealed that factors that positively influence the efficiency of rice producers are: education, membership of farmers based organization, access to extension services, experience in rice production and access to extension services. Adegbola et al. (2006) showed that in central and northern Benin, the most efficient rice farmers are those who use animal traction, herbicides, and improved varieties. Using the Cobb-Douglas production function, Kinkingninhoun-Medagbe et al. (2010) estimated the technical efficiency of irrigated rice farmers in Benin at 0.84. The study found experience in rice production, planting date, and water access as factors influencing technical efficiency of rice producers. Singbo and Lansink (2010) showed that there are about 35% inefficiency in lowland rice production in Benin. The factors determining the inefficiency of these producers are access to water, household size, farm size, and experience in rice production.

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. Age was found in this study as the main source of inefficiency with positive relationship with technical inefficiency and negative association with allocative inefficiency. Analyzing Ivorian rice farmers' efficiency, Nuama (2006) showed that the main factors that influence the efficiency of rice farmers are access to credit, land leasing, ownership of a cash crop farm, and membership of farmers' organization. Omondi and Shikuku (2013) which analyzed the technical efficiency of rice farmers on the irrigation scheme of Ahero in Kenya have found an efficiency score of 0.82. Variables such as gender, farming experience, income, and distance from market are the main factors influencing the technical efficiency of rice farmers. Kadiri et al. (2014) in their study have estimated the efficiency score of rice producers in the Niger Delta region in Nigeria at 0.63. They also identified gender of the farmer and household size as key variables that influence technical efficiency. A study by Heriqbaldi et al. (2015) in 15 provinces in Indonesia concluded that farm size and income are variables that influence the technical efficiency of rice farmers. In Nigeria, Akinbode et al. (2011) estimated the mean technical, allocative, and economic efficiencies at 0.72, 0.92, and 0.67, respectively. In addition, education, contact with extension agents and gender were found to be the sources of technical inefficiency, while age, education, experience in rice production, extension services, and gender, determine allocative efficiency. To determine investment strategies that could improve rice production in Punjab in Pakistan, Kouser and Mushtaq (2007) used the approach of the stochastic production frontier. Results from the inefficiency model showed that investment in agricultural machinery contributes to the improvement of the technical efficiency of rice producers. Agricultural mechanization is undoubtedly a way to increase productivity in the rice sector.

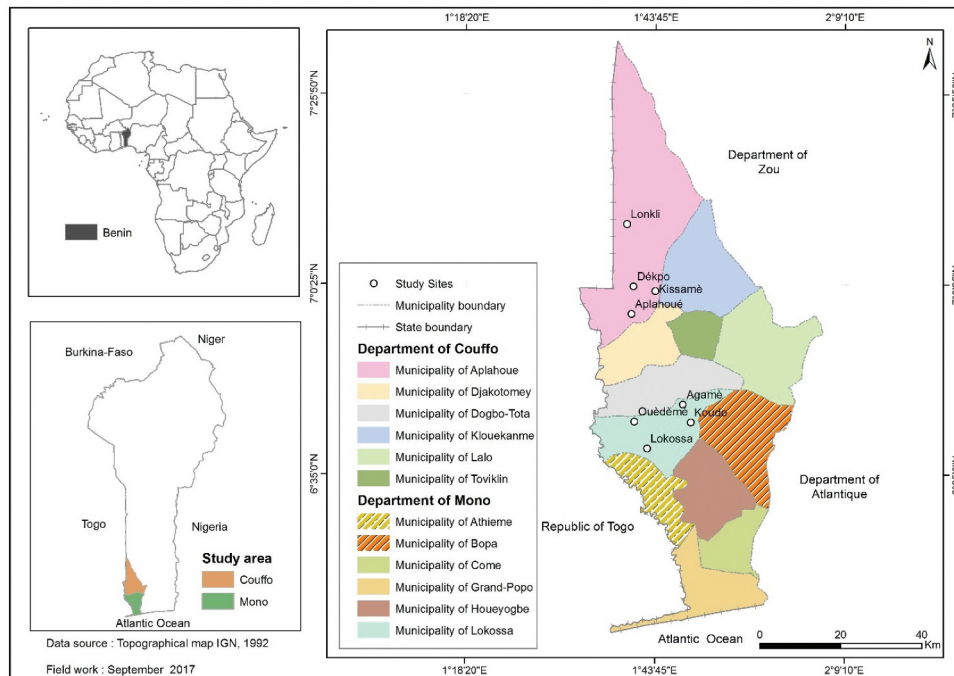
The non-parametric approach was used by Krasachat (2003) and Dhungana et al. (2004) to measure technical, allocative, and economic efficiency in Thailand and Nepal, respectively. Both studies identified the inefficiency factors through the estimation of a Tobit model. A technical efficiency score of 0.71 was estimated for Thailand (Krasachat, 2003). Farm size is the key variable that affects the efficiency of producers. Dhungana et al. (2004) estimated the scores of technical, allocative, and economic efficiency at 0.76, 0.87, and 0.66, respectively. They argued that the difference in producers' inefficiency in Nepal is the result of the difference in use of farm inputs such as fertilizer, seed, labor, and agricultural equipment. In addition, the Tobit model estimate showed that variables such as age, sex, educational, farmer's attitude to risk, and availability of family labor are factors influencing the efficiency of rice farmers in Nepal, while the allocative efficiency is determined by gender and attitude to risk.

3. Materials and methods

3.1. Study location

The study was carried out in Benin in the departments of Mono and Couffo (Figure 1). In Benin, departments are the first-level subdivisions. The country is divided into 12 departments. A department consists of several municipalities which in turn is divided into districts. The departments of Mono and Couffo are located in the South West of the Republic of Benin, between 6 ° 15' and 7 ° 30' North latitude and between 1° 35' and 2 °10' East longitude. They are bordered to the North by the department of Zou, to the South by the Atlantic Ocean, to the West by the Republic of Togo with a natural border which is the Mono River over a length of 120 km, to the East by the Couffo Valley and the Lake Ahémé. The departments of Mono and Couffo cover a total area of 4,009 km² of which 62 % is arable land. Annual precipitation fluctuates around 1100 mm with four seasons, namely a major rainy season between March and July, a minor dry season between August and September, a minor rainy season from September to November and a long dry season from December to March. The average daily temperature ranges from 25 to 29°C with an average of 28°C (Tossou et al., 2017). The atmospheric humidity is always high and frequently 96% on the littoral in Cotonou.

Figure 1. Map of study area.



The departments of Mono and Couffo were chosen for this study because (1) they are among the lowest rice-producing area in Benin, and (2) they have enormous potential agricultural land and agro-ecological conditions suitable for rice cultivation. In fact, these departments have 17,000 ha of lowlands that can be used for rice production and 27,000 ha of floodplains (MAEP, 2011). Despite its potential for agricultural production these departments are characterized by high level of food insecurity and poverty (Table 1) and are classified among the three poorest departments in Benin (INSAE, 2015). Majority of the population are involved in subsistence agriculture and other economic activities such as fishing, livestock, small business, trade and crafts. The main crops produced in the two departments are maize, cassava, cowpea, rice, tomato, pepper, vegetables, cotton, and oil palm. Rice yield in the departments of Mono-Couffo is relatively higher than the average yield in the country. However, a share of small land is devoted to rice production compared to other regions such as Alibori and Atacora. As showing in Table 1, only 0.9% and 1.5% of land under rice production in Benin are in the departments of Mono and Couffo, respectively, while 25% and 32% are in the departments of Atacora and Alibori, respectively. This may explain the deficit in rice production in the departments of Mono and Couffo.

This study used secondary data from the Ministry of Agriculture, Livestock and Fisheries in Benin. This farm-level data contains technical and economic information collected from a sample of rice farmers during the 2012–2013 crop year in the departments of Mono and Couffo with support from the project “Facilité d’Appui aux Filières Agricole du Mono et du Couffo (FAFA-MC)” and the “Centre d’Action Régional pour le Développement Rural (CARDER) du Mono et du Couffo”. The CARDER collected rainfall information from three different areas in the municipality, and these are compiled at the departmental level. Prior to the data collection, the Regional Rice Council (RRC) of the departments of Mono and Couffo carried out census of rice producers in 2011. There were 3, 282 rice producers, in terms of percentage 64% are from the Department of Couffo and 36% from Mono. Based on this distribution of rice producers in the Departments of Mono and Couffo, a proportional sampling technique was used to obtain 210 producers. These regional surveys were designed to collect reliable information on socio-economic characteristics of producers as well as inputs used in rice production, in order to understand agricultural practices and to provide supports for farmers in these regions.

Table 1. Socio-economic 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 activities	Agriculture, fishing, livestock, small business, trade and crafts	Agriculture, fishing, livestock, small business, trade and crafts.	Agriculture, fishing, livestock, small business, trade and crafts.	Agriculture, fishing, livestock, small business, trade and crafts.	Agriculture, fishing, livestock, small business, construction, agribusiness trade and crafts,
Major crops	Maize, rice, cassava, tomato, pepe, vegetables, and oil palm	Maize, rice, cowpea, cassava, cotton, tomato, and pepe	Maize, cassava, cowpea, rice, sorghum, cotton, and cashew.	Maize, cassava, cowpea, rice, sorghum, cotton, and cashew	Maize, Rice, sorghum, Beans, Cassava, Cotton, Cocoa, Pineapple, Cashew, and oil palm
Food insecurity (%)	35.3	44.5	60	45	34
Poverty incidence (%)	46.8	49.3	39.8	42.3	40.1
Rice yield (kg/ha)	3 499	3 086	4 460	2 652	3 417
Area harvested (ha)	1 254	3 005	35 118	19 451	281 428

Source: INSAE (2011, 2015) and MAEP (2018)

3.2. Empirical framework

3.2.1. Technical efficiency model

The stochastic frontier approach was used in this study. This approach was preferred to the non-parametric DEA analysis because it uses the maximum likelihood method which gives more robust results than the DEA method which relies on mathematical programming. In addition, unlike the deterministic approach, other advantage of the stochastic approach is that it differentiates the inefficiency related to producers from that due to random effects not controlled by producers (Aigner et al., 1977; Coelli et al., 2005; Kumbhakar & Lovell, 2000; Meeusen & Van den Broeck, 1977; Onumah et al., 2010). It, therefore, considers the stochastic nature of the agricultural sector. Also, the basic assumption of the non-parametric and deterministic approaches that all deviations from the border are due to farm inefficiency is very unrealistic in the agricultural sector because inefficiency in this sector is also attributable to climatic risks, phytopathology, and harmful insects, government policies, international markets, etc. (Njeru, 2010).

The stochastic production function is represented as follows:

$$Y_i = f(X_i; \beta) \cdot \exp(\varepsilon_i) \tag{1}$$

$$Y_i = f(X_i; \beta) \cdot \exp(v_i) \cdot \exp(-u_i) \tag{2}$$

where Y_i is the level of rice production for farmer i , X_i represents the vector of inputs, and β the vector parameters to be estimated. ε_i is the error term composed of two independent elements v_i and u_i such as $\varepsilon_i = (v_i - u_i)$. v_i is the error term including random factors (climate, poaching, luck, topography, etc.) that are not under the control of rice farmers. u_i is the error term representing

non-negative factors specific to the farm and the farmer and contributing to the rice farmer's inefficiency. The assumptions of the model are: (1) u_i is non-negative and follows a normal distribution with mean μ and variance σ_u^2 ; (2) v_i follows a normal distribution with mean 0 and variance σ_v^2 ; (3) v_i and u_i are independent of each other and independent of the explanatory variables. The variances of interest in this model are $\sigma^2 = \sigma_\mu^2 + \sigma_\nu^2$ et $\gamma = \frac{\sigma_\mu^2}{\sigma^2}$. By definition, γ is between 0 and 1. A value of γ equals to 1 indicates that the deviation of the border is entirely due to technical inefficiency, while a value of γ equals to 0 means that all the deviation of the border is due to random shocks. Thus, if $0 < \gamma < 1$, the variation in production is characterized by the presence of both technical inefficiency and random shocks.

Estimation of the production frontier assumes that the limit of the production function is defined by the farmer with the best agricultural practice. This, therefore, indicates that the maximum potential output for a set of inputs is given by:

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

The technical efficiency (TE) of the rice farmer i is defined as the ratio of observed output to potential output. This is given by Equation (4):

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

Equation (4) shows that the difference between the observed output (Y_i) and the potential output (y_i^*) is embedded in u_i . So if $u_i = 0$, then $y_i = y_i^*$ implying that the production of farmer i is on the production frontier and therefore is technically efficient. If $u_i > 0$ then $y_i < y_i^*$, implying that the production of farmer i is below the production frontier and therefore is technically inefficient.

A Cobb-Douglas production function is used in this study. This was chosen because it is flexible and self-dual (Amegnaglo, 2018; Bravo-Ureta & Evenson, 1994). Other advantage of the Cobb-Douglas production function lies in the easier interpretation of returns to scale. The Cobb-Douglas functional form has been used in several studies including Timmer (1971); Richmond (1974); Kinkinginhoun-Medagbe et al. (2010), Ouedraogo (2015), Adedoyin et al. (2016), Elias et al. (2017), Amaechina and Eboh (2017), and Amegnaglo (2018).

The general form of the model is as follows:

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

where Y_i is the amount of rice produced per hectare; β is the vector of parameters to be estimated; X_{ij} is the vector of inputs used by the rice farmer. It is composed of labor (X1) measured in man-day per hectare, share of hired labor (X2), the amount of local seed used (X3) in Kg/ha, the amount of improved seed used (X4), the amount of fertilizer (X5) in Kg/ha, the amount of herbicide (X6) in liters/ha. We also added soil conditions variables such as clay soil (X7), loamy soil (X8). A dummy variable for the seasons (X9) was included to test whether the production frontier is different for the two seasons (long and short rain season).

3.2.2. Allocative efficiency model

Following the works of Khandaker et al. (1993), Byiringiro and Reardon (1996), Chavas et al. (2005), Ogundari (2008), and Ajoma et al. (2016), allocative efficiency is determined based on the neoclassical theory of production. Thus, there is allocative efficiency when the farm is able to equalize the marginal productivity of each input at its price. Since producers are price takers in the input market, the marginal cost of each input is equal to its price. This approach makes it possible to identify the production inputs that are used inefficiently. This information is useful for policies to improve the use of agricultural inputs. To determine allocative efficiency, average physical product

(APP) and marginal physical product (MPP) were calculated from the estimation of Cobb-Douglas production function (Equation 6) by ordinary least squares (OLS).

$$APP = Y/X_i \text{ and } MPP = \partial Y / \partial X_i * APP = \beta * APP \quad (6)$$

where Y is the mean of rice output per hectare, X_i is the mean of the inputs, and β the estimated coefficients. Value of marginal product (VMP) is calculated by multiplying marginal physical productivity by the price of output (Py). The allocative efficiency (AE) is given by.

$$AE = VMP/P_i \quad (7)$$

With P_i the price of input i. If $AE > 1$ then the input is underutilized and therefore farm profit could be improved by intensifying the use of the input. If $AE < 1$, then the input is overused and its reduction can contribute to the improvement of farm profit. If $AE = 1$, the allocative efficiency is reached and therefore the maximum profit is realized. We used price at farm gate. In Benin as in most developing countries, agricultural marketing is not well organized, and majority of small-holder farmers sold their produces at farm gate. Also, for inputs farmers received fertilizer, seed, herbicide, and other agro-chemicals mainly through extension services and Farmer-based organization (FBO). The labor price includes the labor wage rate and the price of food given to workers.

3.2.3. Inefficiency model

The inefficiency model of rice producers is defined as follows:

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

where δ is the vector of parameters to be estimated; Z is the vector of specific variables that are supposed to be source of inefficiency. It includes: age (Z1) expressed in years, gender (Z2), education (Z3) which is a dummy variable with value 1 if the rice farmer has attained at least primary education and 0 otherwise, farm size expressed in ha (Z4), type of production (Z5) whether the rice farmer produces food grain or seed, the use of improved varieties (Z6), access to credit (Z7) and finally a location-specific variable (Z8) indicating whether the farmer is located in the department of Mono or in the department of Couffo.

3.2.4. Estimation technique

Two main estimation techniques have been used in the literature for analyzing the factors influencing efficiency. These include the two-step estimation method and the one-step simultaneous estimation approach. The two-step approach first requires estimating the production function to determine the efficiency scores, then regressing its derived scores on explanatory variables (generally representing the specific characteristics of the farm and farmers, and institutional variables) using the ordinary least squares (OLS) method or Tobit regression. The major drawback of this two-step approach is that, in the first step, the effects of inefficiency are assumed to be independent and identically distributed in order to predict the values of the efficiency scores. However, in a second step, the efficiency scores thus obtained are supposed to depend on a certain number of socio-economic factors, which implies that the effects of inefficiency are not distributed in an identical manner, unless all the considered factors occur simultaneously. To overcome the limitations of the two-step approach, the one-step simultaneous estimation approach has been proposed (Battese & Coelli, 1995; Reifschneider & Stevenson, 1991). In this model, the inefficiency effects are expressed as an explicit function of a vector of explanatory variables, and all parameters are estimated in a single step using the maximum likelihood procedure. This one-step approach has been used in several studies (Amara & Romain, 2000; Battese & Coelli, 1995; Konja et al., 2019; Kumbhakar & Lovell, 2000; Njikam & Alhadji, 2017; Onumah et al., 2010; Wang & Schmidt, 2002).

In this study, the method of maximum likelihood was used to estimate production functions and inefficiency of rice producers. This was performed in a single step on STATA using the FRONTIER 4.1 program.

4. Results

4.1. Descriptive statistics

Summary statistics of the respondents' profile (Table 2) show that, overall men are more engaged in rice production than women. Indeed, women occupy a secondary position in decision-making processes within the farms. Only 38 % of surveyed rice farmers are educated. This may probably explain the low adoption of rice intensification practices. About 5% of respondents were involved in rice seeds production ensuring local availability of certified seed. Majority (88%) of the rice farmers grow during the major rainy season as they largely depend on rainwater. Due to the lack of guarantee, producers cannot directly access credit from banks. Most of the financial supports received by respondents come from various agricultural projects and programs in the region such as the project "Facilité d'Appui aux Filières Agricole du Mono et du Couffo (FAFA-MC)". However, only 11% of respondents have benefited from this support. This shows the lack of agricultural credit for improving rice production in the departments of Mono and Couffo. Among the producers, 32% have adopted improved rice varieties against 68% who use traditional varieties.

In both departments (Mono and Couffo), the farm size ranges from 0.25 ha to 5 ha with an average of 1.7 ha. The quantity of seeds used per hectare varies between 25 kg and 100 kg with an average of 64.5 kg per hectare which is higher than the recommended seeds rate of 60 kg per hectare. A significantly higher proportion of farmers (73%) in the department of Couffo used fertilizer compared to those in the department of Mono (39%). The average quantity of fertilizer (78.1 kg ha^{-1}) and herbicide ($0.7 \text{ Liter ha}^{-1}$) were very low. For instance, the agricultural extension services recommended a rate of fertilizer application between 150 and 250 kg per hectare depending on the type of production. Rice yield per hectare varies from 1002.7 kg to 4533.3 kg with an average of 2658.6 kg ha⁻¹ in Couffo and 2315.5 kg ha⁻¹ in Mono. Low yields are observed among rice producers suggesting that there is still a potential for improving rice yield in the departments of Mono and Couffo. Analysis of the difference in yield among farmers in the two departments reveals that there was no gender difference ($t = -0.22$). Higher yield was observed among rice farmers that use fertilizer ($t = -1.93$), herbicide ($t = -3.06$), improved seed ($t = -2.32$), and those who have access to credit ($t = -3.00$).

A comparative analysis of the respondent profile between the departments of Mono and Couffo shows that there was no significant difference regarding the age, gender, type of culture, use of improved seed, use of irrigation, access to credit, quantity of local seed, quantity of herbicide, share of hired labor, use of herbicide, clay soil, and average prices of fertilizer, herbicide, seed and labor. Respect to the farm variables, significant differences were noted. Rice farmers in Couffo department have a larger farm size and benefit from a relatively good rainfall condition (Table 2). They also use more fertilizer compared to farmers in Mono. However, farmers in Mono department employed more labor probably because they used relatively less hired labor or more family labor compared to those in the Couffo department. This is an indication that there is surplus of family members who spend too much time in rice production in Mono department compared to the department of Couffo. In term of rainfall, the department of Couffo (about 1200 mm) benefits from a good rainfall pattern than the department of Mono (about 983 mm). While the two departments have in majority clay soil, the department of Couffo has more loamy soil compared to Mono department.

4.2. Estimations and determinants of technical efficiency

4.2.1. Estimates of stochastic production model and technical efficiency scores

Estimation results of the stochastic production model are presented in Table 3. The coefficient of gamma is very close to 1 and is significantly different from zero. This suggests the presence of

Table 2. Profile of the respondents in Mono and Couffo departments

Variable definition and Measurement	Average	Mono	Couffo	t-test/Chi2
Age (Years)	41.4	40.1	42.1	-1.12
Farm size (ha)	1.7	1.3	1.9	-3.85***
Seed (kg/ha)	64.5	59.2	67.4	-3.43***
Quantity of local seed (kg/ha)	21.86	23	21.23	0.37
Quantity of improved seed (kg/ha)	44.92	38.08	48.73	-2.14**
Fertilizer (kg/ha)	78.1	45.4	97.4	-4.86***
Herbicide (Liter/ha)	0.72	0.82	0.62	1.64
Farm labour (man days/ha)	258.3	281.9	245.3	1.65*
Share of hired labour (%)	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***
Use of irrigation (Yes = 1, No = 0)	0.11	0.13	0.10	0.64
Gender (Male = 1, Female = 0)	0.68	0.70	0.67	0.08
Education (At least primary school = 1, None = 0)	0.38	0.48	0.32	5.35**
Type of culture (Consumption = 1, Seed = 0)	0.95	0.97	0.94	1.12
Use of improved seed (Yes = 1, No = 0)	0.68	0.68	0.67	0.007
Access to credit (Yes = 1, No = 0)	0.11	0.12	0.10	0.13
Use of fertilizer (Yes = 1, No = 0)	0.60	0.38	0.73	24.34***
Use of herbicide (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
Loamy soil(Yes = 1, No = 0)	0.15	0.04	0.22	12.08***
Average price of fertilizer (FCFA/kg)	248.94	242.6	252.42	-0.97
Average price of herbicide (FCFA/L)	1397.97	1694.6	1233.14	1.39
Average price of seed (FCFA/Kg)	349.38	353.52	347.38	0.77
Average price of labour (FCFA)	1845.79	1822.6	1858.63	-0.43

Note: *** Significant at 1%; **Significant at 5 %; *Significant at 10 %

Table 3. Estimates of stochastic production model parameters

Production variables	Coefficient	Probability
Share of hired labour	-0.008 (0.038)	0.826
Labour	0.070*** (0.019)	0.000
Traditional seed	0.072** (0.036)	0.044
Improved seed	0.191*** (0.053)	0.000
Fertilizer	0.085*** (0.026)	0.001
Herbicide	0.048** (0.024)	0.043
Rainfall	0.527** (0.265)	0.031
Clay soil	0.175*** (0.065)	0.007
Loamy soil	0.115 (0.075)	0.119
Irrigation	-0.008 (0.036)	0.804
Season	-0.042 (0.048)	0.382
Constant	-0.338* (0.173)	0.068
Gamma	0.985***	0.002
Wald Chi2 (11)	79.11***	
Log likelihood	40.39	

Note: *** Significant at 1%; ** Significant at 5%; *Significant at 10%. Value in parenthesis are robust standard errors.

technical inefficiency among rice producers in the departments of Mono and Couffo. Therefore, the assumption of absence of inefficiency is rejected at 1%. The estimation results show that all the variables such as labor, seeds, fertilizer, herbicide, rainfall, and clay soil contribute significantly to increase rice yield in the departments of Mono and Couffo. The non-significance of the irrigation variable could be explained by the fact that very few producers (11%) use irrigation techniques. Seeds contribute more to yield than other agricultural inputs considered. A 1% increase in improved seeds will result in a 19% improvement in rice yield. Producers who used a higher amount of improved seed per hectare performed better. These results confirm those of Shabu (2013) and Oppong et al. (2014) who showed that seeds contribute about 25% to rice and maize production, respectively, in Nigeria and Ghana.

Herbicide and labor are the inputs that contribute the least to rice production in the departments of Mono and Couffo. This highlights the need to modernize agriculture in Benin through strong mechanization and adoption of new technologies. These results are in line with those obtained by O Gundari (2008) and Oppong et al. (2014). On the other hand, Chirwa (2007) showed that labor is the main contributor to production in Malawi because production is more intensive. We also found that soil type is an important factor in increasing rice productivity. Farmers who have clay soil have

Table 4. Distribution of technical efficiency (TE) scores and yields

Yield TE	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

higher productivity compared to those with loamy and sandy soils. In fact, clay soils provide stagnant water, which increases the productivity of water and rice (Tsubo et al., 2007).

The estimated technical efficiency varies from 42% to 99% with an average of 78% (Table 4). About 7% of producers have their technical inefficiency scores less than 50%. The results imply that there are opportunities to increase rice production in the short term by adopting better farming practices. These results are similar to those previously obtained by Krasachat (2003), Dhungana et al. (2004), Adegbola et al. (2006), Yabi (2009), Kinkinginhoun-Medagbe et al. (2010), Singbo and Lansink (2010), Kadiri et al. (2014), Konan et al. (2014), and Ouedraogo (2015), who have shown that there are opportunities to increase rice production. Producers would therefore benefit more by improving the use of productive resources.

Cross-analysis of efficiency scores with producer yields shows that 50% of producers have a level of efficiency greater than 80% and a yield greater than 2500 kg ha⁻¹. There is therefore a strong positive correlation ($r = 0.90$) between the level of efficiency and the producer's yield. Thus, the highest efficiency levels are associated with the highest yields. This implies that the most efficient producers have a better return. Improving the level of efficiency would therefore lead to an increase in the producer's output.

Table 5. Estimates of the technical efficiency model parameters

Variables	(1) All	(2) Mono	(3) Couffo
Age	0.028*** (0.010)	- -	0.029** (0.012)
Gender	0.500* (0.258)	0.52 (0.540)	0.499* (0.275)
Education	-0.747*** (0.289)	-1.59* (0.825)	-0.047* (0.026)
Farm size	-0.143 (0.095)	-0.07 (0.146)	0.532*** (0.038)
Type of culture	-0.489 (0.614)	1.47 (2.796)	-0.558 (0.555)
Use of improved seed	-0.312 (0.313)	-1.22** (0.603)	0.040 (0.299)
Access to credit	-3.116*** (1.527)	-0.82 (1.240)-	-1.271*** (0.385)-
Location	-0.421 (0.304)	- -	- -
Constant	-2.273*** (0.898)	-2.83 (3.120)	-2.379*** (0.897)

Chow Test [K, N-2*K] = 3.0195 P-Value > F(8, 194) = 0.0032

Note: *** Significant at 1%; ** Significant at 5%; *Significant at 10%. Value in parenthesis are robust standard errors.

4.2.2. Determinants of technical efficiency

Table 5 presents the results of the technical inefficiency model. Overall, the variables that influence technical inefficiency (model 1) are age, gender, education, and access to credit. The Chow test ($P\text{-Value} > F(8, 194) = 0.0032$) applied to this model indicates that the determinants of technical efficiency are different in the two departments (models 2 & 3). The coefficient of age is positive and significant implying that older producers are less efficient than younger ones who are more receptive to technical changes in production that influence efficiency (Singbo & Lansink, 2010; Khan & Ali, 2013; Opong et al., 2014). The coefficient of the variable gender is considered positive. This implies that male farmers are less efficient than women farmers. This is probably due to the fact that women generally do not have access to productive resources (Amegnaglo, 2018), and thus will be forced to allocate their resources more efficiently. The coefficient associated with the education variable is negative and significant. This implies that the level of education of producers contributes to the reduction of inefficiency in rice production. This result is in line with previous work (Battese & Coelli, 1995; Elias et al., 2017; Yabi, 2009) which showed a positive relationship between education and the technical efficiency of producers.

Access to credit has negative and significant coefficient, suggesting that accessibility to credit reduces the inefficiency of rice producers in the departments of Mono and Couffo. Several studies (Elias et al., 2017; Nuama, 2006; Opong et al., 2014; Yabi, 2009) have shown that access to credit is a positive factor for increasing efficiency of producers because producers can purchase inputs in time and avoid delays in farming activities (Bjornlund & Pittock, 2017; Mdemu et al., 2017; Nonvide et al., 2018).

4.3. Estimation and determinants of allocative efficiency

4.3.1. Estimation of allocative efficiency

The coefficient of allocative efficiency for labor (0.08) is less than 1 (Table 6). This is an indication that the labor input factor is overused in the departments of Mono and Couffo. Indeed, rice production system in Benin remains traditional with most of the activities carried out manually. For example, activities including bush clearing, seedlings, or transplanting, weeding, and fertilizer application are still done entirely manually. Some times and depending on farmers' financial capacity, activities including tillage and harvesting are done with tractor or ox plough. There is inefficiency in the use of labor in the departments of Mono and Couffo. None of the producers use the labor efficiently. A reduction in the workforce would increase the profit of the producer. This result confirms those previously obtained by Ogundari (2008).

The allocative efficiency for seeds was estimated at 2.49, which is greater than 1. This result indicates that the seed input is underutilized in rice production in the departments of Mono and Couffo in Benin. Thus, producers would benefit from increasing the quantity of seeds used. Similar results were found by Ogundari (2008), Ajoma et al. (2016), and Amaechina and Eboh (2017) who showed sub-optimality in the use of seeds by producers. The coefficients of the allocative efficiency for fertilizer and herbicide are, respectively, 1.58 and 2.21, indicating that fertilizer and herbicides are underutilized in rice production in the departments of Mono and Couffo in Benin. This can be explained by the fact that the majority of rice producers do not apply the recommended rate for the use of fertilizers and herbicides because of the high cost of these inputs. For example, 83% of rice producers in both departments apply fertilizer rates below the recommended standard of 150 to 250 kg/ha. These results confirm those found by Ajoma et al. (2016) and Amaechina and Eboh (2017). Rice producers in the departments of Mono and Couffo would therefore benefit greatly from an increase in the amount of use of fertilizers and herbicides. However, the results suggest that farmers need to increase herbicide use more than fertilizer. This may be because the use of herbicide remains very low among rice farmers. Only 28% of the rice farmers used herbicide against 60% who used fertilizer.

Table 6. Shows the value of the marginal product of each input and the allocative efficiency scores. The results indicate no significant difference between the two regions (Mono and Couffo in terms of labor ($t = -0.46$), seed ($t = -0.007$), fertilizers ($t = -1.16$), and herbicide ($t = -0.52$). The analysis of the results indicates that none of the production inputs is used efficiently in the departments of Mono and Couffo

Variable	APP			MPP			VMP			AE = VMP/P _i		
	All	Couffo	Mono	All	Couffo	Mono	All	Couffo	Mono	All	Couffo	Mono
Labour	14.17	14.57	13.45	1.04	1.07	0.99	157.38	161.82	149.39	0.08	0.08	0.07
Seed	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
Herbicide	379.27	355.13	422.72	18.58	17.40	20.71	2787.65	2610.22	3107.01	2.21	2.31	2.06

APP = average physical product, MPP = marginal physical product, VMP = Value of marginal product, AE = Allocative efficiency and P_i price of input *i*.

4.3.2. Determinants of allocative efficiency

Table 7 presents the results of the determinants of allocative efficiency. Overall, the variables that affect allocative inefficiency (Model 1) are age, gender, area planted, type of culture, and access to credit. The Chow test ($P\text{-Value} > F(8, 194) = 0.0044$) revealed that the determinants are different between the two regions (Mono and Couffo). This is also confirmed by the fact that different set of variables are significant for the two regions (models 2 & 3).

The variable age has a negative and significant coefficient. This implies that the younger producers allocate their resources more efficiently than the older ones. This can be explained by the fact that young people have limited access to resources. The results are consistent with those obtained by Akinbode et al. (2011) and Ouedraogo (2015) who have shown that age is an allocative efficiency factor and that younger people have a better allocation of resources compared to older ones. The gender coefficient is negative and significant, indicating that women are less efficient than men. This result is in line with previous studies (Akinbode et al., 2011; Amoussouhoui et al., 2012; Dhungana et al., 2004) showing that allocative efficiency is negatively affected by the gender of the producer.

The positive relationship observed between the areas planted and allocative efficiency shows that the large-scale producers allocate the resources better, given their importance. Thus, they will benefit from economies of scale. The results also indicate a positive coefficient for the variable type of culture. This suggests that production for consumption is more allocative efficient than seed production. In fact, there is a significant difference in rice seeds prices and rice price for consumption. Seeds producers paid about 485 CFA for 1 kg of seeds while those who produce rice for consumption paid 342 CFA. There is also a positive relationship between access to credit and allocative efficiency. Timely provision of financial resources would enable the producer to acquire the inputs as quickly as possible (Bjornlund & Pittock, 2017; Mdemu et al., 2017; Nonvide et al., 2018).

Table 7. Determinants of allocative efficiency

Variables	(1) All	(2) Mono	(3) Couffo
Age	-0.009*** (0.003)	-0.010* (0.006)	-0.013*** (0.004)
Gender	-0.171** (0.081)	-0.298* (0.178)	-0.005 (0.102)
Education	0.105 (0.078)	0.018** (0.009)	0.106 (0.100)
Farm size	0.041*** (0.002)	0.032 (0.057)	0.037*** (0.002)
Type of culture	0.454*** (0.129)	0.065 (0.163)	0.502*** (0.153)
Use of improved seed	0.080 (0.093)	0.428*** (0.158)	-0.174 (0.129)
Access to credit	0.566*** (0.115)	0.409** (0.271)	0.722*** (0.136)
Location	0.107 (0.081)	- -	- -
Constant	1.172*** (0.256)	1.527*** (0.364)	1.455*** (0.336)

Chow Test $[K, N-2 \times K] = 2.9050$ $P\text{-Value} > F(8, 194) = 0.0044$

Note: *** Significant at 1%; ** Significant at 5%; *Significant at 10%. Value in parenthesis are robust standard errors.

5. Discussion

Previous studies in Benin covered diverse regions in the country and employed different method of analysis. Some studies (Amoussouhoui et al., 2012; Singbo & Lansink, 2010) employed the two-stage approach while other (Kinkingnihoun-Medagbe et al., 2010; Yabi, 2009; Zannou et al., 2018) used the single-step estimation of the stochastic production frontier. Our study complements these previous studies. It focuses on departments of Mono and Couffo, which are among the lowest rice-producing regions in Benin. Unlike previous studies, we applied the neoclassical theory of production to determine the production inputs that are used inefficiently. This constitutes the value-added of our study on efficiency in Benin. We found that none of the production variables are used in an efficient way. Labour was overused while seeds, fertilizer, and herbicide were underutilized.

The mean technical efficiency score was estimated at 78% for the farmers producing rice in the departments of Mono and Couffo. This suggests that there are opportunities for increasing farmers' efficiency. This finding is supported by previous studies (Amoussouhoui et al., 2012; Kinkingnihoun-Medagbe et al., 2010; Singbo & Lansink, 2010; Yabi, 2009; Zannou et al., 2018) which have shown that there is at least 16% inefficiency in rice production in Benin. For instance, Yabi (2009) recorded a technical efficiency estimate of 0.82 for rice farmers in Benin. In irrigated rice farming, Kinkingnihoun-Medagbe et al. (2010) recorded an estimate of 0.84. Singbo and Lansink (2010) also documented about 35% inefficiency in lowland rice production in Benin. These studies reveal that rice farmers in Benin would benefit from a better and efficient use of productive resources. Overall, this result is within the range of efficiency scores (65 to 92%) found in previous studies (Kinkingnihoun-Medagbe et al., 2010; Singbo & Lansink, 2010; Yabi, 2009) in Benin, and is consistent with results from other countries (Dhungana et al., 2004; Kadirir et al., 2014; Konan et al., 2014; Krasachat, 2003; Ouedraogo, 2015). The estimated mean efficiency is 0.80 for rice farmers in Burkina Faso (Ouedraogo, 2015), 0.72 in Nigeria (Akinbode et al., 2011), 0.76 in Nepal (Dhungana et al., 2004).

Our results provide evidence that there is potential for increasing rice production in the departments of Mono and Couffo. Better allocation of production factors would allow rice producers in the departments of Mono and Couffo to achieve economies of scale. For this, there is a need for strong institutional support measures. According to our results, two key policy variables are education and credit. The Oaxaca-Blinder decomposition test showed that if the uneducated producers were educated, their technical efficiency would be improved by 4.2% and also if they had the same characteristics, it would increase their technical efficiency score by 9.5%. Similarly, if producers who did not have access to credit receive credit, their technical efficiency score would be improved by 2.8%. Moreover, when they have the same characteristics as those who have access to credit, this could improve their technical and allocative efficiency by 9.6% and 52.6%, respectively. Improving farmers' education on good agricultural practices would therefore enable farmers to increase crop management practices and efficiency, and hence rice production. Numerous studies (Elias et al., 2017; Oppong et al., 2014) have shown that access to credit is an important factor in increasing the efficiency of producers. With credit, farmers can secure agricultural inputs on time and avoid delays in agricultural activities (Bjornlund & Pittock, 2017; Nonvide, 2019).

6. Conclusion

In this study, we estimate and assess factors that affect technical and allocative efficiency among rice farmers in the departments of Mono and Couffo in Benin. A stochastic frontier approach is estimated to measure technical efficiency, and allocative efficiency is measured using a marginal value product approach. Furthermore, a Chow test was performed to test for difference in determinants of efficiency between the two departments. Several conclusions can be drawn from this study: (1) the technical efficiency of the producers was estimated at 78%, (2) the rice producers overused the labor, and underused other factors of production such as seeds, fertilizer, and herbicide, (3) sources of inefficiency were age, gender, education level, and access to credit. These findings imply that there are still potential for improving rice production in the departments of Mono and Couffo. Thus, it is necessary to organize periodic trainings for producers

on good production practices. In this regard, extension services can play an important role. Improving the efficiency of producers also depends on the use of agricultural technologies. It is therefore important to facilitate access to these technologies for producers. The efforts of the government and organizations involved in the agricultural sector must also be geared towards promoting agricultural credit. Access to credit is a key factor in the development of the agricultural sector.

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