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Type and Technical, Allocative and Economic Efficiencies in Agricultural Production: The Case of Women Market Gardeners in the Ouémé Valley in Southern Benin

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Abstract

The objective of this study is to analyse the technical, allocative and economic efficiencies in the market gardening production in the Ouémé Valley, southern Benin. To this end, a descriptive and analytical study was carried out on a sample of 472 randomly selected market gardeners in the Ouémé Valley, distributed in Dangbo, Adjohoun, Bonou and Aguégués.

The technical and economic efficiency scores were estimated, respectively, using stochastic frontier models of the Cobb-Douglas type and a dual cost function. The *Tobit* regression model was used to identify the factors determining the economic efficiency of women producers. The results show that female market gardeners are on average technically efficient. However, the results from the production and cost frontiers indicate the presence of technical and allocative inefficiencies within the production units. The estimated technical, allocative and economic efficiency scores are on average 0.921, 0.893 and 0.823 respectively. Finally, the estimation of the determinants of efficiency showed that age, area and farm labour are the main determinants of economic efficiency of market gardeners in the Ouémé valley. Based on the results obtained, it is important to improve the efficiency of market gardeners and thus increase their profits through a policy of light mechanisation of the activity and the strengthening of technical support for the organisation of women producers.

Keywords: efficiencies; stochastic boundaries; Cobb-Douglas function; market gardening; Ouémé Valley.

1.Introduction

The issue of women's empowerment has become an important concern at the centre of global sustainable development policies. The inequality between women and men in societies in terms of well-being, power, access to and control over resources has over the decades prompted reflections aimed at creating the basis for actions that can improve the situation of women the author in [1].

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Because of their significant contribution to economic activities, the responsibility of women in the functioning of the national economy is becoming more and more perceptible throughout the world. Through many activities, in various sectors, women play a key role in the socio-economic development of nations. However, although they do 66% of the work and produce 50% of the food worldwide, women receive only 10% of the income, accounting for 70% of the 1.3 billion people living on less than $1 a day Avadí and his colleagues in [2]).

In sub-Saharan Africa, peri-urban market gardening supplies fresh vegetables to growing cities and is generally carried out by women. In Benin, market gardening is an important source of employment and income in urban and peri-urban areas, and especially on the banks of rivers and/or in the valleys of certain areas Author in [3]. It is a source of cash income for many producers in these specific areas. In the Ouémé valley in southern Benin, market gardening is the main activity, in terms of occupation and income, for the majority of women who engage in this agricultural activity.

The income generated by market gardening enables dozens of thousands of families to meet their various needs and constitutes an effective alternative for escaping a situation of economic precariousness due to poverty author in [3]. The demand for market garden produce in Benin is mainly met by conventional systems, mainly via public markets. In fact, the sector satisfies all domestic needs for market garden produce, so imports of market garden produce are negligible according to [3]. The market gardening sector has developed rapidly as a result of the galloping population growth that has led to an increase in food needs in the urban centres of southern Benin (Yehouenou and his colleagues in [4]). To meet the needs of urban populations, especially for high value-added food resources such as vegetables and fruit, three types of market gardening systems can be distinguished in southern Benin. These are the so-called conventional, reasoned and organic vegetable farms. Conventional vegetable production systems predominate and are based on the use of organic and/or mineral fertilisers and synthetic chemical pesticides. To optimise crop yields in most of these vegetable farms on sandy soils in the coastal sedimentary basin of southern Benin, there is often over-fertilisation of organic and/or mineral fertilisers and excessive and inappropriate use of pesticides.

Despite the economic and social importance of this activity, which provides a good part of the population's food and nutritional resources, it still remains one of the non-mechanised agricultural activities, the vast majority of which is carried out by human labour in Benin (Avadí and his colleagues in [3]). One exception that is becoming more widespread is irrigation. Although the majority of producers use manual irrigation, simple sprinkler irrigation systems are increasingly being used by the more successful producers who also use solar pumping systems for water supply. (Author in [5]). In addition to these difficulties encountered by the actors in this activity, there are other constraints linked to the organisation of the sector and, consequently, the estimation of the surface area cultivated with vegetables and the identification of production areas suffer from a lack of precision (Djohy and his colleagues in [6]. Nevertheless, some information and statistical data on production volumes, yields and marketing of market garden products reveal that the most widely consumed vegetables are tomatoes, leafy vegetables, fruiting vegetables and onions, but the statistics do not take into account the type of market garden system. For each of these vegetables, there is inconsistency in production from year to year (sometimes increasing, sometimes decreasing), with yield levels fluctuating authors in [3]. However, in general, the areas planted have improved significantly in recent years at national level. According to official statistics, the area under tomato cultivation increased from 31,623 ha in 2008 to 37,968 ha in 2012, with production ranging from 184,526 to 244,742 tonnes and yields from 5,835 to 6,446 t/ha. Thus, the area and yield increased by 20 and 10.5% respectively, while production increased by 33% between 2008 and 2012. For leafy vegetables, the recorded area sown was 9,665 ha in 2012, an increase of 27% compared to 2008 when the area sown was 7,588 ha. Yields rose from 4 972 to 7 455 t/ha, and production from 37 731 to 72 055 tonnes, i.e., an increase of 50% and 91% respectively over the period. As for fruiting vegetables, the area sown went from 227 to 1 693 ha between 2008 and 2012, an increase of 646%. Yields rose from 7,046 to 18,404 t/ha, and production from 1,952 to 31,156 tonnes, i.e., an increase of 161 and 1,496% respectively. Avadi and colleagues in [3]. In analysing this evolution of areas and yields, this study looked at the technical, allocative and economic efficiency of women engaged in this activity. It is with this in mind that the study aims to estimate the levels of technical, allocative and economic efficiency of women market gardeners in the Ouémé valley and to identify the determining factors of these efficiencies. This study is structured in four (04) main sections. After this introductory section, the second section presents the materials and methods, then the results are presented in the third section, and finally, the last section discusses the results.

2. Concepts and effectiveness assessment methods

2.1 Efficiency concepts

The measurement of efficiency has emerged in the work of [7] work on the analysis of production and (Debreu 1951) who introduced the resource utilisation coefficient. In 1957, Farrell established that firm efficiency can be empirically calculated and proposed, for the first time, a radial method of estimating efficiency frontiers from the observation of real production situations. According to [8], the production frontier indicates the maximum quantity of output obtained from each combination of inputs and the determinants of productive efficiency can only be examined if it has been previously estimated. According to literature, the concept of efficiency has three components, namely technical, allocative and economic efficiency Aminou and his colleagues in [9]. The first component of efficiency refers to the material organisation of production. According to (authors in [10]), for a given factor endowment, the technical efficiency of a firm is measured as the difference between the observed level of production and the maximum level of production determined by the production frontier.

Thus, a farmer is technically efficient if, for a given level of inputs and outputs, it is impossible to increase the quantity of one output without increasing the quantity of one or more inputs or reducing the quantity of another output (Choukou and colleagues in [11]). The most technically efficient farmer is the one who, at the same level of output, used the least number of inputs or, at the same level of inputs, obtained more output. Technical efficiency is measured by the difference between the observed level of output and the potential level of output determined by the production frontier. From the point of view of the production frontier, a production unit is technically efficient when it is on the frontier, i.e., it manages to achieve the highest possible level of output for a given level of input or it manages to use the least possible input for a given level of output, autours in [12]. Geometrically, it is defined as the distance between any observed level of output and the maximum level that would be obtained if all inputs were used efficiently. For authors in [5] for example, a firm can be said to be technically inefficient when it is not on its production frontier; that is, with a given quantity of inputs, it does not achieve the highest technically feasible level of output. The second component of efficiency is defined in relation to the price system faced by the operator and according to economic optimisation behaviour (cost minimisation, profit maximisation) Nuama and colleagues in [13]. The third component is the result of the first two components. Thus, authors in [5] states that the operator, who is both technically and allocatively efficient, is said to be economically efficient.

This overview of the concept corresponds to that of and his colleagues in [16] who notes that achieving one of the two types of efficiency may be a necessary but not sufficient condition for achieving economic efficiency. It emerges that a firm is only economically efficient if it is technically efficient (or has the best technical and material organisation) and allocates its productive resources efficiently; both conditions must be achieved simultaneously.

2.2 Methods for estimating production and cost boundaries

In any efficiency analysis, the estimation of production and cost boundaries is a fundamental first step according to the literature. Several methods are used by authors for efficiency assessment. They can be classified into two main families of commonly applied methods and differ in the way the frontier is constructed, and thus, the efficiencies are calculated. These are the parametric or econometric approach known as *Stochastic Fronctier Anlysis* (SFA), and the so-called non-parametric approach based on mathematical programming known as *Data Envelopment Analysis* (DEA). Each of these approaches and the techniques they contain have advantages and limitations in their application and are widely described in the literature. The choice between the two approaches is not always easy. (Fecher-Bourgeois and colleagues in [17]) The authors recommend using the knowledge of the technology of the sector under study as a basis. These authors believe that when one has a fairly clear idea of what the underlying technology is, as in the case of the agricultural sector and manufacturing industries, for example, estimating efficiency using the parametric approach makes sense. However, in the case of a decision unit whose activity is the production of services, a parametric approach is no longer applicable because it is not based on any explicit assumption about the technology and it applies to activities with several outputs and several inputs.

Several frontier estimation methods exist to estimate the parameters of the parametric approach. These methods can be classified according to the assumed shape of the production or cost frontier, the estimation technique used to obtain it and the nature and assumed properties of the difference between observed and maximum output authors in [5]. According to Amara and his colleagues [18] was the originator of the deterministic frontier specification. He proposed the approximation of the efficient production function by a functional form known a priori. Thus, an easier specification and a better analysis of the different algebraic properties of this function become possible. He used the Cobb-Douglas functional form to illustrate the use of this approach on agricultural data from 48 American states, while imposing constant returns to scale. According to (Kumbhakar and colleagues in [19]), this method can accurately determine, based on a sample of observations, the maximum quantity of output (i.e. the frontier) and any difference between this quantity and the observed quantity arises solely from inefficiency. The specified function of a deterministic frontier can be estimated either by statistical inference or by non-statistical methods authors in [20] . The major disadvantage of these procedures is that they do not provide the statistical properties of the estimators.

Indeed, in addition to its limitations dictated by the deterministic nature of the production frontier, the deterministic parametric approach is subject to two other criticisms. Firstly, it is very sensitive to extreme observations and, secondly, the assignment of a functional form to the frontier function is restrictive, in the sense that each functional form implicitly reflects a number of assumptions authors in [21]. Thus, this notion of a deterministic frontier neglects the possibility that a firm's performance may be affected by factors beyond its control, such as weather, poor machine performance or input shortages, whose effect is as important as factors within the firm's control. These arguments led to the development of the stochastic or compound error approach authors in [22].However, there is a second possibility for estimating a parametric frontier: the stochastic approach.

This stochastic frontier approach is simultaneously proposed by Aigner and colleagues in [23]. It consists in specifying in the error term two components: (1) one captures the effects of inefficiency with respect to the frontier and (2) the other captures the effects of measurement errors and other white noise outside the producers' control. Indeed, these factors cannot be negligible, especially in agriculture, which is always affected by recurrent climatic hazards and repetitive natural disasters that negatively affect the productivity of agricultural inputs and thus plunge farmers into a vicious circle of poverty. The random effect was introduced by (authors in [24]) to account for factors beyond the control of the farmer. The estimation of the stochastic production frontier can be done using econometric methods (the corrected least squares method and the maximum likelihood method).

The non-parametric approach was proposed in the initial work of authors in [7] and involves the use of linear programming techniques to address the shortcomings of the parametric approach, it does not require the specification of a particular functional form of the production technology and does not introduce any parameters to formalise, a priori, the relationship between inputs and outputs. However, since this approach is deterministic, it assumes the absence of random errors (Albouchi,and his colleagues in [25]). In practice, several methods can be used to construct the frontier and determine efficiency levels, but the *Data* Envelopment Analysis (DEA) method is the most widely used non-parametric method. With the latter, production boundaries are constructed using linear programming to solve primal and dual optimisation problems. According to authors in [26], this approach does not take into account the random errors that could influence the efficiency or inefficiency of a farm, and its use is only desired in cases where the production sectors whose efficiency is being analysed have very small random effects. A multitude of outputs, difficulties in determining prices and where cost or profit optimisation decisions are not a priority. Thus, for sectors without these characteristics, for example, the agricultural sector, the parametric approach based on the determination of a production frontier is recommended. Two types of frontiers are distinguished: the deterministic frontier and the stochastic frontier.

2.3 Determinants of effectiveness

The existing literature elucidates some determinants of efficiencies authors [27] indicates that the gender of the farmer, the use of improved seeds, the selling price of maize, the share of off-farm income, contact with an

NGO, access to credit, and the area of production are preponderant factors of efficiencies. In a study to measure the performance of olive producers in the Chbika region of Tunisia, author in [28] states that, the age of the farm managers, the level of education, the access to credit and the proportion of productive trees are significant and positively influence the level of technical efficiency of olive farms in Chbika, while off-farm income and access to land reduce the technical efficiency of these farms. In southern Benin, (Ahouangninou and his colleagues [28]) In a study analysing the technical, allocative and economic efficiencies in the production of greater nightshade, the age of the producer, the area sown, the contribution of greater nightshade to income, the level of education and technical training are the main determinants of the technical, allocative and economic efficiencies of greater nightshade producers.

In neighbouring countries such as Côte d'Ivoire, authors in [5] analysed the technical efficiency of Ivorian rice farmers and found that the main determinants of the productive efficiency of the rice farmers in his sample were membership of a self-help group, access to credit, access to land through renting, and ownership of a cash crop farm. The author also showed that extension as currently practiced by the rural extension service is not an effective determinant of the reduction of technical inefficiency of the rice farmers in the sample. For authors in [29], the age of the farm manager, modern capital, and the fact that rice is grown only on the same farm, on all the plots and fields of the farm are determinants of efficiency.

3. Methodology

3.1 Study area

This study takes into account Ouémé valley which covers the communes of Dangbo, Adjohoun, Bonou and Aguégués. Ouémé valley, located in the south-east of the Republic of Benin, is a magnificent place, ranked as the second richest valley in the world after the Nile. The Ouémé valley is mainly watered by Ouémé river called "Wogbo". It is the largest and longest river in the region and even in the Republic of Benin. It is the biggest influence in the region compared to all other regions crossed in the north of the country. The region also has important streams, canals and a middle valley formed by a tributary of Ouémé river called the Zou River. It comprises two ecologically different zones: - The base valley known as "Wogbo" located on either side of the river which is completely flooded during flood periods (flood period from July to October). The Plateau or height of the Valley called "Aguédji" shows many places with picturesque views over the whole Base Valley and even the cities of Cotonou, Calavi and others thus offering an immense tourist wealth. The main economic activities of the lower Ouémé valley are fishing, agriculture, livestock, trade, crafts and hunting. Fishing is the main activity of the population. It is practised all year round, but the most productive fishing period is from August to September, when the flooding begins.

3.2 Database

The data used in this study are primary data collected through a survey conducted by Oxfam. The survey was conducted in the study area, Ouémé valley. This valley was chosen for the study because of the importance of market gardening in the valley and the contribution of this activity to the empowerment, well-being and food security of the women who engage in this activity. After the communes of Dangbo, Adjohoun, Bonou and Aguégués were selected for the study, the villages in which the survey was to take place were randomly selected. The farms in our sample were selected at random with a sampling rate of 50% of all market garden farms identified by the agricultural advisors of the Territorial Agricultural Development Agency (ATDA) in the study area. A total of 1,300 vegetable farms are listed in the census file of agricultural advisors in the study area. A sample of 650 vegetable farms was drawn at random, but of the 650 selected, we chose to focus only on plots owned by women. Thus, the statistical unit is the market garden plot managed by a woman. A structured questionnaire was administered individually to women producers during the period of May 2019 and resulted in 472 women producers being surveyed. The commune of Dangbo provided 120/472, or 25.43%; the commune of Adjouhoun provided 110/472, or 23.31%; the commune of Bonou provided 130/472, or 27.54%, and the commune of Aguégués provided 112/472, or 23.73%. The main information collected during the data collection phase relates to the socio-demographic characteristics of the market gardeners, their cultivation practices, unit prices and quantities used of inputs and production factors as well as prices and quantities produced of market garden produce in order to analyse their efficiency in the production of this crop in Ouémé valley in Benin as well as the factors determining these efficiencies.

3.3 Analysis models and data collection

3.3.1 Estimating technical efficiency scores

The parameters of the stochastic production frontier were estimated by the maximum likelihood method. The Cobb-Douglas type technology functional form was chosen over the *translog* specification based on χ2 statistical tests of the likelihood ratio. Considering a market gardener who combines factors of production (land, capital, labour and technology) to produce a good $QPROD$ (market garden produce), the stochastic production frontier is represented by the following specified form:

$$Ln(Prod_i) = \beta_o + \beta_1(lnSup_i) + \beta_2(lnCompos_i) + \beta_3(lnCredit_i) + \beta_4(lnTrav_i) + \mathcal{V}_i - \mathcal{U}_i \quad (1)$$

Where, i represents the producers of maize i= 1 … … … … . . n

n The sample size ; β_i The vector of parameters to be estimated; it represents the production elasticities because the production function is of the Cobb-Douglas type; $Prod_i$ Quantity of marketed vegetables; $Compos_i$Quantities of composites used in kg; $Credit_i$: Amounts received from financial services for vegetable farming; $Trav_i$Amount of labour used (family and or hired labour) in man-days/ha; $\mathcal{V}_i$: is the random error term ; $\mathcal{U}_i$: is the error term that reflects the technical inefficiency of the farmer i and Ln is the neperian logarithm. Two assumptions are to be considered concerning the error terms: it is assumed that $\mathcal{U}_i$ follows a normal distribution with parameters $\mathbb{N}(0, \sigma_{\mathcal{U}}^2)$ and $\mathcal{V}_i$ follows a truncated normal distribution, i.e. $\mathcal{V}_i \to \mathbb{N}(0, \sigma_{\mathcal{V}}^2)$. On the basis of these assumptions, we obtain from the FRONTIER program of Coelli, (1998), the coefficients and

$$\sigma^2 = \sigma_{\mathcal{U}}^2 + \sigma_{\mathcal{V}}^2 \quad (2)$$

$$\lambda = {}^{\sigma_u}/_{(\sigma_u + \sigma_v)} \qquad (3)$$

and λ measures the share of technical inefficiency in the total variation observed between the points on the production frontier and the data. The technical efficiency indices are calculated by the following formula and obtained in Stata 13 software.

$$TE_i = \exp(-U_i) \qquad (4)$$

3.3.2 Estimating economic and allocative efficiency scores

To estimate the economic and allocative efficiency scores, the dual cost frontier function of the Cobb-Douglas type was used to estimate the efficiencies. The specification of the dual cost frontier function is as follows:

$$Ln(CT_i) = \beta_o + \beta_1 ln(P.\text{compos}_i) + \beta_2 ln(P.\text{terre}_i) + \beta_3 ln(Taux_i) + \beta_4 ln(P.Trav_i) + \mathcal{V}_i - \mathcal{U}_i$$

With :

$Ln(CT_i)$The logarithmic value of the cost of market gardening of vegetables of producer i expressed in CFAF/kg; $Prod$ Quantities of market garden produce marketed; $P.compos$: average price of organic matter in FCFA/kg; $P.terre$: average price of land rental in FCFA/ha; $P.travail$: price of labour (occasional + family) in FCFA/HJ; rate : interest rate of the credit in percentage and Ln the neperian logarithm.

After obtaining the economic efficiency (EE), it can be decomposed into technical and allocative efficiencies. The allocative efficiency (EA_i) is therefore estimated by the following equation:

$$EA_i = \frac{EE_{i)}}{ET_{i)}} \qquad (5)$$

With: EE_ieconomic efficiency and ET_i technical efficiency.

3.3.3 Estimating the determinants of economic efficiency

The method frequently used to explain efficiency levels is the two-step method according to the literature presented above. It consists, first of all, in estimating the efficiency levels of the different farmers, then in regressing these efficiency levels according to some specific factors such as: the size of the farm, the age and the level of education of the farmer, the access to credit, the training received by the farmer and his membership to a group, the sown area, the gender. Thus, the regression carried out during this second stage can follow the linear regression model or the Tobit model to take into account the truncated character (between 0 and 1), the dependent variable in this model is the economic efficiency (EE). The equation of this model is in the following form:

$$EE_i = \alpha_0 + \sum a_i X_i + e_i \qquad (6)$$

With X_i the explanatory variables (Table 2).

The main potential determinants of the efficiency levels of vegetable production are presented in the Table *8* in the appendix.

4. Results

4.1 Descriptive statistics of the variables used

Descriptive statistics for some of the main variables in our data that were used to estimate the efficiencies are presented in Table 2. From these statistics, we note that the average age of the women market gardeners is 30 (±5.35) and varies from 19 to 45 years. The average cultivated area is 0.57 (±0.24) ha and varies from 0.21 ha to 1.18 ha. The average amount of compost used is 5.39 (±1.8925) Kg/ha and varies from 1Kg to 11Kg/ha. As for the finished product, i.e., the quantity of market garden produce, it is on average 46,752 (± 46,752) FCFA/ha, with a strong variation from 12 to 98 Kg. As for the amount of credit, it is on average 35983.05 (±10078.45) FCFA/ha. The amount of credit granted to women varies from 15,000 to 65,000 FCFA/ha and a labour of 5.23 (2.24) HJ

Table 1: Descriptive statistics of variables.

Variables	Obs	Mean	Std. Dev.	Min	Max
Age	472	30.661	5.3596	19	45
Area	472	0.5762	0.2419	0.21	1.8
Quantity of organic material	472	5.3961	1.8925	1	11
Quantity of market garden	472	46.752	18.251	12	98
Amount of credit received	472	35983	10078	15000	65000
Quantity of agricultural labour	472	5.2923	2.2401	1	250

Source: Author, survey data, 2021

4.2 Estimating the parameters of the production frontier model

The stochastic production frontier as presented above is of the Cobb-Douglas type, which is the most suitable for the technological specificities of this activity. The estimates were carried out using the maximum likelihood (ML) method under the *Frontier* program of *Stata 13* software. The estimation results are presented in Table 3. The results show that the model is well specified and overall significant at the 1% level (Wald chi2(6) = 65.42 and Prob > chi2 = 0.003). The results reveal a λ value below unity (λ=0.27) and significant at 1%, indicating the presence of technical inefficiency at the level of female producers. This λ value also shows that the women farmers could achieve better yields with the same factor endowments. The presence of technical inefficiency was tested using the maximum likelihood ratio test (chibar2(14) = 76.91, Prob>=chibar2 = 0.000). The null hypothesis tested is that all the market gardeners surveyed are technically efficient. The results of this test reject the null hypothesis of no technical inefficiency at the 1% level. In addition, the coefficient of the parameter $\sigma_v{}^2$In addition, the coefficient of the parameter in the production function equation is significantly different from zero at the 1% level. Therefore, the variation in output observed at the level of the production units studied is partly due to random effects. The results reveal that the elasticities of the production frontier are -0.074, 0.132, 0.079, 0.002 for area, organic matter, capital and labour respectively. Indeed, all explanatory variables except area revealed positive and significant elasticities at the 5% threshold on the production frontier. These results therefore indicate that vegetable production is influenced by factors such as: organic manure, financial capital and labour.

Table 2: Parameter estimation results of the production frontier model.

Explanatory variables	Coef.	Std. Err.	z	P>z
Area	-0.074716	0.0457456	-1.63	0.102
Amount of organic matter	0.1321182***	0.0438756	3.01	0.003
Credit amount	0.0798173**	0.0644444	1.24	0.016
Amount of Work	0.0027137**	0.0366916	0.07	0.041
Constant	2.756025***	0.8155962	3.38	0.001
N = 472 Wald chi2(6) = 65.42 Prob > chi2 = 0.003 Likelihood-ratio test of sigma_u=0: chibar2(14) = 76,91; Prob>=chibar2 = 0,000				
/lnsig2v ($\sigma_v{}^2$)	-1.958254***	0.3082103	-6.35	0.000
/lnsig2u ($\sigma_u{}^2$)	-4.510543	10.652100	-0.42	0.672
sigma_v (σ_v)	0.375639	0.0578879		
sigma_u (σ_u)	0.1048451	0.5584099		
sigma2 (σ^2)	0.1520971	0.0752368		
Lambda (λ)	0.2791113	0.6150443		

***Significant at 1%; **Significant at 5%.

Source: Our Results, 2021

4.2 Estimating the parameters of the cost frontier model

The parameter estimation results of the production cost model are presented in the Table 3: Parameter estimation results of the cost frontier model. The results show that the model is well specified and overall significant at the 1% level (Wald chi2(5) = 1.52 and Prob > chi2 = 0.0107). The results reveal a λ value greater than unity (λ=1.7915) and significant at the 1% level, indicating the presence of allocative inefficiency at the producer level. Also, this λ value shows that producers could achieve the current yields with a relatively lower cost. The presence of allocative inefficiency was tested using the maximum likelihood ratio test (chibar2(01) = 13.87 Prob>=chibar2 = 0.000). The null hypothesis tested is that all market gardeners surveyed are located on the cost frontier, i.e., are allocatively efficient. The results of this test reject the null hypothesis of no allocative inefficiency at the 1% level. Further on, the coefficient of the parameter $\sigma_u{}^2$The coefficient of the parameter in the cost function equation is significantly different from zero at the 1% level. Therefore, the variation in cost observed at the level of the production units studied is partly due to the inefficiency effects of producers. Of the five (05) variables introduced into the model, three (03) are significant at the 5% level. The quantity produced is significant at the 5% level with a positive effect on the cost of production. An increase in production of 1% leads to an increase in production cost of 0.001014%. In contrast, the land rent has a negative and significant effect on the cost of production at the 5% threshold. The higher the land rent, the lower the average cost of production. The average price of labour also affects the cost of production negatively and significantly at the 5% threshold.

Table 3: Parameter estimation results of the cost frontier model.

Variables	Coef.	Std. Err.	z	P>z
Production	0.0010144**	0.0142605	0.07	0.043
Average price of the compound	-0.000766	0.010242	-0.07	0.940
Average land price	-0.006087**	0.0093781	-0.65	0.016
Average price of labour	-0.0028647***	0.021245	-0.13	0.003
Financial interest rate	0.0117599	0.0111932	1.05	0.293
Constant	6.370981***	0.2651756	24.03	0.000
Wald chi2(5) = 1.52 Prob > chi2 = 0.0107 Log likelihood = -329.44598 Likelihood-ratio test of sigma_u=0: chibar2(01) = 13.87 Prob>=chibar2 = 0.000				
/lnsig2v ($\sigma_v{}^2$)	-4.978751***	0.1483733	-33.56	0.000
/lnsig2u ($\sigma_u{}^2$)	-3.812567***	0.1579942	-24.13	0.000
sigma_v (σ_v)	0.0829618	0.0061547		
sigma_u (σ_u)	0.1486317	0.0117415		
sigma2 (σ^2)	0.028974	0.0029616		
Lambda (λ)	1.791569	0.0163107		

*Source: Our results, 2021; significance at 1%, **: significance at 5%.*

4.3 Distribution of technical, economic and allocative efficiency scores

The descriptive statistics of the calculated efficiency scores are presented in the Table *5* in the appendix. The average technical efficiency score obtained is 0.921 and varies from 0.885 to 0.941. These results do not indicate that any of the market gardeners are on the production frontier. The distribution of the market gardeners according to the efficiency classes (Figure 1) shows that all the market gardeners achieved a technical efficiency score of over 90%. This result is very encouraging and shows that market gardeners in Ouémé valley are not far from the ideal in terms of optimal combination of production factors and technology. Furthermore, the allocative efficiency score obtained is 0.893 and varies from 0.660 to 0.972. The least allocatively efficient producer has a score of 0.660 and the most efficient one has a score of 0.972.

These results reveal appreciable performance in the allocation of productive resources among market gardeners in Ouémé valley. The distribution of scores shows that only 2.75% of the women obtained a score below 75%, even though none of the market gardeners obtained a score of 100%. The combined effect of the two types of efficiency is measured by the economic efficiency. For this study, the average score was 0.823 and varied between 0.594 and 0.912. The distribution graph of the economic efficiency scores shows that 92.80% of the market gardeners obtained a score equal to or higher than 75%. In addition, the results of the test comparing the average scores according to the "educated or not" status of the market gardeners (Table *5*) showed that educated women are technically more efficient than uneducated women with a significant difference at the 5% level (Pr(T < t) = 0.0200). The allocative and economic efficiencies show no significant difference between women with and without basic education.

4.4 Determinants of economic efficiency

The results of the analysis of the factors affecting the economic efficiency indices are obtained from a *Tobit* regression carried out using *Stata 13* software

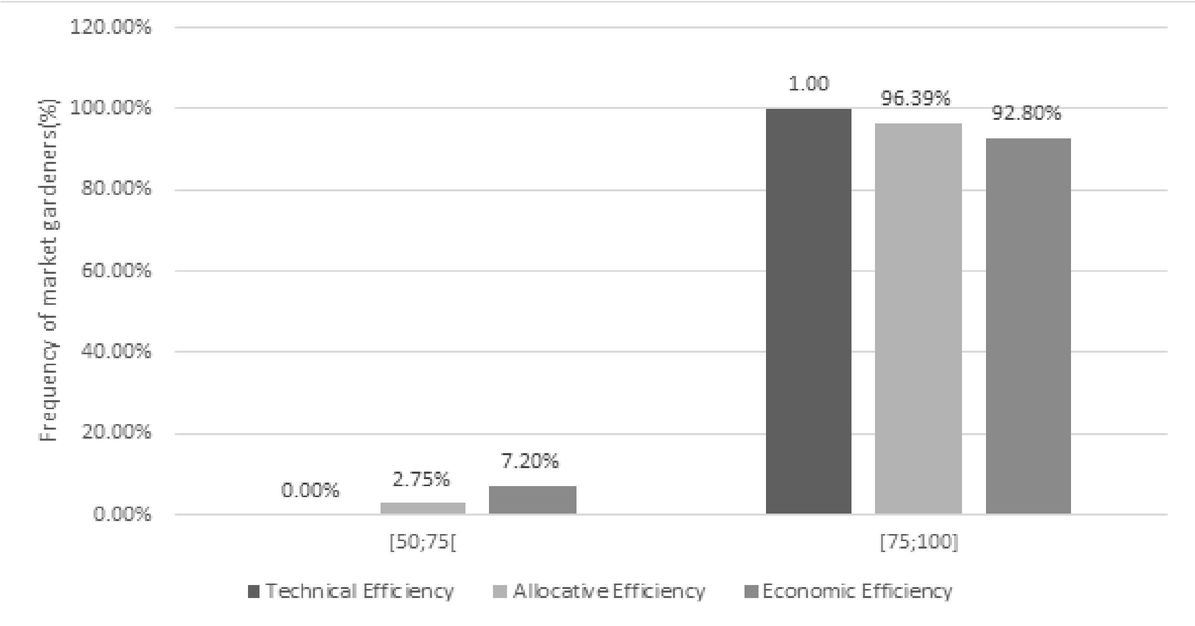

Figure 1: Distribution of efficiency scores.

Source: Our Results, 2021

and the results are presented in the Table *4*. These results reveal that age, area and agricultural labour are the main factors determining the economic efficiency of market gardeners in the Ouémé valley. The positive correlation between age and the economic efficiency score shows that older women market gardeners are more economically efficient than younger ones. The coefficient of the area variable in the determinant analysis model of economic efficiency is positive and significant. Economic efficiency increases with the size of the area farmed.

The amount of farm labour is positively correlated with the economic efficiency of the market gardeners; the more farm labour the market gardener has, the more efficient she seems to be. Labour is therefore an important factor in improving the economic efficiency of this activity in Ouémé valley.

Table 4: Determinants of economic efficiency.

Economic efficiency	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
ages	0.00008**	0.00078	0.10	0.017	-0.00146	0.00162
Number of children	-0.00733	0.00833	-0.88	0.380	-0.02380	0.00912
Areas	0.01345**	0.01853	0.73	0.029	-0.02317	0.05008
Extension assistance	0.00103	0.00950	0.11	0.913	-0.01775	0.01982
Member of agricultural cooperatives	-0.01001	0.00927	-1.08	0.282	-0.02834	0.00831
Modern storage methods	0.00217	0.00806	0.27	0.788	-0.01376	0.01810
Agricultural labour	0.00335**	0.00179	1.87	0.043	-0.00018	0.00689
Quantity of composites used	0.00149	0.00219	0.68	0.047	-0.00280	0.00582
The following is a list of some of the most important issues that have been raised in the last few years.	0.77386*	0.02850	27.15	0.000	0.71753	0.83020
/sigma	0.04899	0.00278			0.04349	0.05448
Number of obs = 472 LR chi2(8) = 6.59 Prob > chi2 = 0.0121 Log likelihood = -247.34329 Pseudo R2 = -0.7135						

*Source: Our results, 2021; *: significance at 1%, **: significance at 5%.*

5. Discussion of the results

In this section, we discuss the different results obtained in this study.

5.1 Analysis of producer efficiency

The analysis of the results of the estimation of the parameters of the production and cost functions of market gardeners in Ouémé valley revealed the presence of technical and economic inefficiencies. The average technical, allocative and economic efficiencies are respectively 0.921, 0.893 and 0.823. These scores compared to those found by (Authors in [29]) are better. Indeed, these authors analysed the technical, allocative and economic efficiencies in the production of greater nightshade in southern Benin and found that the technical, allocative and economic efficiencies averaged 0.689, 0.882 and 0.607 respectively. This discrepancy between the scores can be explained by the fact that our study is based on the female gender, whereas these authors worked on both sexes. Our results are not so far from those found by authors in [5] who measured the technical efficiency of female food crop farmers in Côte d'Ivoire. This author specified the female gender and at the end of the investigations, it appears that female producers are on average technically efficient in the food crops considered. Indeed, the average indices of technical efficiency are respectively 0.88 and 0.80 for yam and cassava. The analysis of the determinants of the production frontier shows that factors such as the quantity of organic matter, financial capital management and labour management are the most significant factors that improve the technical efficiency of women producers. As for the cost frontier, it is determined by factors such as good negotiation of average land rental prices and casual or permanent labour. These results corroborate those of author in [6] which indicate that the labour force represented by household size has a significant positive impact on food crop production. Our results also reveal that educated women are more technically efficient than uneducated women with a significant difference in technical efficiency scores. Educated women farmers are likely to be better at applying new technologies taught by extension agents than uneducated ones.

5.2 Analysis of the determinants of effectiveness

The analysis of the determinants of the economic efficiency of women producers reveals that age, area and agricultural labour are the main factors determining the economic efficiency of market gardeners in the Ouémé valley. The positive correlation between age and economic efficiency score shows that older women market gardeners are more economically efficient than younger ones. This positive effect of age on the economic efficiency of women producers challenges the conclusions of author in [6] which stated that the older women producers get, the less efficient they become. This age effect has been widely discussed in the literature and must be put into perspective and contextualised. It should be noted that our sample consists of women aged between 19 and 45. Our results also reveal that economic efficiency increases with the size of the area planted. Women farmers are at the scale efficiency stage, so increasing production results in lower average cost of production and, therefore, a positive effect on efficiency. These results are similar to those of (Ahouangninou and his colleagues in [30]) who found that the age of the producer, the area planted, the contribution of nightshade to income, the level of education and technical training are the main determinants of technical, allocative and economic efficiencies of nightshade producers. Our results on the factors determining economic efficiency support those of several authors in the literature (Gandonou, Chogou, and his colleagues in [31]; .

6. Conclusion

The objective of this study was to evaluate the technical, allocative and economic efficiency of women market gardeners in Ouémé valley and to analyse the determinants of this productive efficiency. The results of the investigations show that women producers are on average efficient. The average technical, allocative and economic efficiencies are 0.921, 0.893 and 0.823 respectively. Market gardening in Ouémé valley is a labour-intensive activity with low financial capital intensity. The pressure on labour, which is becoming increasingly scarce in the area, is a major constraint for women producers and, consequently, light mechanisation programmes must be urgently directed towards these producers for a sustainable and efficient intensification of this activity, which is essential for the empowerment of women in the valley. A significant effort should be made to organise women into groups, as the fact that women producers belong to a group does not have a significant effect on economic efficiency. Women should be supported and accompanied in their organisation within cooperatives to better organise themselves in order to benefit from access to financing from microfinance structures and support from agricultural extension structures.

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Annexes

Table 5: Descriptive statistics of effectiveness scores.

Variable	Obs	Mean	Std. Dev.	Min	Max
Technical Efficiency	472	0.921	0.009	0.885	0.941
Allocative Efficiency	472	0.893	0.058	0.660	0.972
Economic Efficiency	472	0.823	0.054	0.594	0.912
Group	Comparison test of technical efficiency scores				
0	157	.9202895	.0007798	.9187493	.9218298
1	315	.9221781	.000518	.9211589	.9231973
combined	472	.9215499	.0004336	.9206978	.922402
diff		-.0018886	.0009172	-.003691	-.0000861
diff = mean(0) - mean(1)			t = -2.0589		
Ho: diff = 0		degrees of	freedom = 470		
Ha: diff < 0	Ha: diff	!= 0	Ha: diff > 0		
Pr(T < t) = 0.0200	Pr(T > t)	= 0.0401	Pr(T > t) = 0.9800		

Table 6: Comparison test of allocative efficiency scores.

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
0	157	.8929591	.0048519	.0607947	.8833751	.9025431
1	315	.8935256	.0032513	.0577043	.8871286	.8999226
combined	472	.8933372	.0027013	.0586863	.8880292	.8986452
diff		-.0005665	.0057393		-.0118444	.0107114
diff = mean(0) - mean(1)				t = -0.0987		
Ho: diff = 0			degrees of	freedom = 470		
Ha: diff < 0	Ha: diff	!= 0		Ha: diff > 0		
Pr(T < t) = 0.4607	Pr(T > t)	= 0.9214		Pr(T > t) = 0.5393		

Table 7: Comparison test of economic efficiency scores.

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
0	157	.8217175	.0044579	.0558578	.8129118	.8305232
1	315	.8240065	.0030416	.0539832	.818022	.829991
combined	472	.8232451	.0025116	.0545652	.8183099	.8281804
diff		-.0022891	.0053353		-.012773	.0081949
diff = mean(0) - mean(1)					t = -0.4290	
Ho: diff = 0			degrees of	freedom = 470		
Ha: diff < 0		Ha: diff	!= 0	Ha: diff > 0		
Pr(T < t) = 0.3340		Pr(T > t)	= 0.6681		Pr(T > t) = 0.6660	

Table 8: Description of the study variables.

Variables	Measures	Expected signs
Age	Continuous variable (in years)	±
Marital status of women	Binary variable (1 = married, 0 = not)	-
Number of children	Continuous variable	+
Market garden areas	Continuous variable	+
Basic instruction	Binary variable (1 = Yes, 0 = No)	±
Quantities of composites used	Continuous variable	+
Market access	Binary variable (1 = Yes, 0 = No)	+
Amounts received from financial services	Continuous variable	+
Agricultural labour	Continuous variable	+
Participation in off-farm activity	Binary variable (1 = Yes, 0 = No)	+
Contact with extension services	Binary variable (1 = Yes, 0 = No)	+
Monthly expenditure on agricultural training	Continuous variable	+
Monthly expenditure on health	Continuous variable	+
Member of agricultural cooperatives	Binary variable (1 = Yes, 0 = No)	+
Modern storage methods	Binary variable (1 = Yes, 0 = No)	+
Agricultural extension assistance	Binary variable (1 = Yes, 0 = No)	+

Table 9: Descriptive statistics of variables.

Variables	Obs	Mean	Std. Dev.	Min	Max
ages	472	30.66102	5.359628	19	45
Number of children	472	2.271186	.5279615	1	5
Market garden areas	472	.5762076	.2419617	.21	1.8
Marital status of women	472	.5084746	.5004586	0	1
Quantities of composites used	472	5.396186	1.8925	1	11
Marketed quantities of vegetables	472	46.75212	18.25137	12	98
Basic instruction	472	.6673729	.4716541	0	1
Market access	472	.2521186	.4346897	0	1
Amounts received from financial services	472	35983.05	10078.45	15000	65000
Agricultural labour	472	5.292373	2.240172	1	9
Participation in off-farm activity	472	.3199153	.4669383	0	1
Monthly expenditure on agricultural training	472	5250.604	6566.062	1054	65430
Monthly expenditure on health	472	2457.646	2016.155	1000	24560
Member of agricultural cooperatives	472	.565678	.4961935	0	1
Modern storage methods	472	.5127119	.5003687	0	1
Agricultural extension assistance	472	.3199153	.4669383	0	1
Price of the vegetable basket	472	490.4873	58.76359	320	650
Annual labour costs	472	67104.43	18264.76	34650	150700