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TECHNICAL AND ECONOMIC EFFICIENCY OF RICE PRODUCTION IN THE KOU VALLEY (BURKINA FASO): STOCHASTIC FRONTIER APPROACH

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Abstract

The present paper seeks to deal with the issue of technical and economic efficiency of rice producers in the Kou valley, located in the region of the high basins in the western part of Burkina Faso. The stochastic frontier approach was used to estimate the production function, from a Cobb-Douglas stochastic frontier function and its dual which allow the estimation of the technical, allocative and economic efficiencies. The determinants of efficiency were simultaneously assessed along with the frontier functions through the FRONTIER 4.1 software. The data used herein are from a survey encompassing 130 rice producers, randomly chosen. Results show that farm size, fertilizer used, years of experience and literacy are the explicative factors of rice production in the Kou valley. The costs of the different production factors significantly contribute to explain the total production cost, and that is in concordance with the economic theory. The technical, allocative and economic efficiencies of producers are, on average, 80.15%, 92.7% and 74.43% respectively. A 25% improvement of rice production is possible if producers optimize their economic efficiency.

Keywords: Technical efficiency, allocative efficiency, economic efficiency, rice, Kou Valley, Burkina Faso

1. INTRODUCTION

Among the food products, rice has continued to be the most important cereal in term of consumption by more than 2.6 billion people in the world. The contribution to global production indicates 92% from Asia, 5% from America and West Indies, and 3% from Africa.

Africa meets roughly 10% of the domestic demand, subsequently absorbing 1/3 of global imports. Burkina Faso is no exception. Local rice production meets about 40% of domestic demand for rice. The deficit has to be met with ever growing imports (Alliance, 2010). Around 89 million dollars were spent from the national budget in 2011 and 105 million dollars in 2012.

The cost burden of these imports brought the country to support special measures to boost local productivity so as to enable food self-sufficiency. Given the scarcity of the means of production, an assessment of the impact of producers' efforts to increase production is necessary in order to enable an efficient implementation of local productivity improvement policies.

The present paper proposes an analysis of technical, allocative and economic efficiency of rice producers of the Kou Valley in Burkina Faso. A strong emphasis is put on production and cost

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function of rice productive input, economical level of efficiency of producers, and finally, the significant determinants that influence this level of efficiency.

2. METHODOLOGY

2.1. Study area

The target area is located in the west of Burkina Faso. It is the agricultural region per excellence with regard to soil fertility in addition to abundant rainfall. This area is part of the government's targeted regions to implement sustainable rice production. The Kou Valley (VDK), located in the Houet province has an average rainfall above 800 mm which is sufficient enough for rice production activities. Rice production is inextricably dependent on water availability. The VDK has a high water potentials from the Kou river, which enables intensive rice production through double annual production cycles. The choice of this area has also been motivated by the important rice production in the region (23% of the country rice farms, 46% of national rice production), the years of experience in rice farming at the VDK (40 years of experience), and the availability of supportive facilities as well as technical partnership able to consolidate the benefits from rice farming.

2.2. Data collection

Data were collected using statistical survey conducted among rice producers in the Kou Valley. A sample of 130 farm owners was randomly selected out of the eight (8) rice farmers' cooperatives of the VDK. 10% of owners from each cooperative were selected.

The study also encompasses secondary sources of data in addition to survey data. These secondary data were sourced from literature review and statistics obtained from the "Direction Générale de la Promotion de l'Economie Rurale" which is the Rural Economy Directorate.

2.3. Conceptual framework

2.3.1. Efficiency concept

In theory, the concept of efficiency refers to two key concepts: technical efficiency and allocative efficiency.

- The first concept refers to the productive input mix. In that sense, a producer is said to be technically efficient when considering a set of factors and inputs, it is impossible to increase the quantity of a product without increasing the factor aspect or decrease the quantity of another product. For the same level of production, the most technically efficient producer is the one that uses less input.
- The second concept is known as price efficiency, as faced by the producer in terms of economic optimisation performance - (cost reduction, profit maximisation.). For example, a producer is said to be allocatively efficient when given a certain level of production, the production cost is kept to a minimum.

Producer who is both technically and allocatively efficient is said to be economically efficient. He maximises on profit. In other words, his profit is maximized because he equalizes the marginal cost of production for each input to its market price.

According to traditional microeconomic theory, studies on technical or economic efficiency are irrelevant, given the fact that the producer is supposed to be rational and a profit maximizer. As a result, the producer always appears to be either on production frontier or cost frontier. In real life, it is quite the opposite as demonstrated by several studies. In fact, producers in general never stand either on production frontier or cost frontier as experience shows.

Several empirical studies that were subsequently conducted across various activities domains and throughout continents to assess the exact level of efficiency of producers (Thiam *et al.*, 2001)

2.3.2. Efficiency estimation methods

The measurement of efficiency first appeared in the work of Koopmans (1951) related to production analysis, and Debreu (1951) who introduced resource utilisation coefficient. Farrell (1957) has established that the efficiency of a farm can be measured and thus submitted for the first time a radical measurement method of efficiency frontier based on the observation of real production situations.

According to Farrell, technical efficiency is used to measure the decision making about the quantity of inputs used in the production process, when their proportions are given. The price efficiency or allocative efficiency is used to measure the firm's decision making about the different inputs proportions in comparison to the admittedly competitive market price. In theory, a production process is considered to be allocatively efficient if the marginal rate of substitution between each pair of inputs is equal to their proportional prices. Economic efficiency is the product of both technical efficiency and price efficiency. Bravo *et al.* (1997) found that this is related the capability for a firm to produce a predetermined output at minimum cost for a given technology set.

However, across years, the methodology as developed by Farrell has known a larger utilization leading to some major improvement. From those major changes, the stochastic model was developed, allowing to measure for the first time technical, allocative and economic efficiency, using maximum likelihood measurement method. Aigner *et al.* (1977), Meeusen and Van (1977) were among the first to develop the stochastic frontier production function. Aigner *et al.* (1977) extended this analysis method to agriculture in the United State (US). Battese and Corra (1977) applied this method to analyse a pastoral zone in Eastern Australia. Meeusen and Van (1977) extended this method to analyse 10 manufacturing industries in France. And more recently, empirical analyses were conducted by Battese and Coelli (1993), Beloume (1999), Ojo (2004) and Nuama (2006). The method used in this paper is based on Battese and Coelli (1995), and Battese *et al.* (1996) work. According to this specific method, the stochastic frontier encompasses inefficiency effects and any other parameters related to production or cost function measured simultaneously.

2.3.3. The efficiency analysis method

The assessment of technical efficiency and allocative efficiency is achieved through the assessment of production frontier and cost frontier of the rice farmers. The type of frontier chosen is the stochastic production and cost frontier (called composed errors frontier) in addition to the incorporated effects of inefficiency proposed by Battese and Coelli (1995). This model was introduced in literature by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1997). This type of production frontier offers the advantage of explaining deviations observed between random production frontier and actual productions observed from the technical inefficiency of the farmer on one side, and on the other side, random factors such as climate factors and other explanatory variables that are omitted.

Mathematically, if we assume that an individual farmer combines a set of given factors of production (land, labour, fixed capital and variable capital) to produce some goods Y (rice), the stochastic frontier production is obtained by using the following equation:

$$LnYi = Ln\, f(Xi\,;\,\beta)\ exp\ (Vi\text{-}Ui)\ (1)\ where\ Ui = \Sigma\, \delta i\ Zi + Wi \qquad \text{.......................} (1)$$

Exp is the exponential function;
Yi = the output of individual farmer i;
Xi = vector of input quantities used by the farmer i. These inputs include:

a) The cultivated land (Sup in hectare);
b) Total labour man/days in farming the land (including men, women, children labour);
c) The quantity of seed used by the farmer;
d) The quantity of fertilizer used;
e) The quantity of pesticide used;
f) The capital representing the value of other inputs and equipment;
β: The Vector of unknown parameters to be estimate; it represents the elasticities when the production function is based on Cobb-Douglas's type;
Vi: The random error term;
Ui: The error term that expresses the technical inefficiency of an individual farmer;
Zi: The socio-economic characteristics that explain the producer's technical inefficiency with:
Z1: Years of experience expressed by the number of years spent in growing rice;
Z2: The household size;
Z3: Binary variable to describe farmer's level of education, that takes 1 if the farmer can read and write in French or local language and 0 if not;
Z4: Binary variable, 1 if farmer invest in other activities apart from growing rice, and 0 if not;

Two hypotheses come into consideration when it comes to error terms: it is assume that Ui follows a normal distribution with parameters N(μ ; σ2u) and Vi a truncated-normal distribution that is to say N(0 ; σ2v).

Based on these hypotheses, Coelli (1996) Frontier software version 4.1, leads to the coefficients and to σ2 = σ2u + σ2v; γ = σ2u/ (σ2u + σ2v). γ measures the technical inefficiency of the total variable observed between the production frontier points and the data.

Considering Y* the maximum frontier output;

$$Y^* = f(Xi ; \beta) \exp(Vi) \qquad \text{..................... (2)}$$

Based on this function, the technical efficiency index of the farmer i is given by the following equation:

$$ET = Yi / Y^* \text{ where } ET = f(Xi ; \beta) \exp(Vi\text{-}Ui) / f(Xi ; \beta) \exp(Vi) \qquad \text{..................... (3)}$$

Therefore ET = exp (-Ui)
The cost function of an individual farmer i is formulated as follows:

$$C_i = g(y_i, p_i, \alpha)\exp(V_i + U_i) \quad = 1, 2, ..., n \qquad \text{........................ (4)}$$

Where C_i = the total cost incurred during the production process;

Y_i = the quantity of rice produced;

P_i = the cost vector of inputs used. All inputs are assumed to be variable and to have market price;

α = vector of parameters to be estimated;

V_i and U_i are defined as shown above.

The allocative efficiency (AE) index is defined as:

$$AE_i = \frac{C_i^*}{C_i} = \exp(U_i) \qquad o \le AE \le 1 \qquad \text{....................... (5)}$$

Where C_i is the total production cost incurred, and C_i^* is the stochastic frontier cost.

This programme assesses cost efficiency (CE), which, conversely, corresponds to the allocative efficiency index ($CE = \frac{C}{C^*}$).

$AE = {}^{1}\!/_{CE}$ The AE index of the individual farmer is shown in the following relationship:

The production and cost frontier functions are estimated through the method of maximum likelihood (ML) using Frontier 4.1 software (Coelli, 1996). It consists in setting the likelihood function and then determines the parameters that maximize this function. The Frontier 4.1 software provides iterative production frontier and cost frontier elasticities, technical efficiency and cost efficiency scores, and significant coefficients.

To estimate cost and production functions as well as the associated parameters, Cobb-Douglas functional form will apply. The advantage of this functional form is that it admits a self-dual, allowing to easily analyse economic efficiency.

3. RESULTS

3.1. The socio-economic characteristics of farm households

Table 1 shows the socio-economic characteristics of farm households. The average age of household heads is 49, showing a relatively younger population. Years of experience in rice farming is between 3 and 40 years with an average of 33 years. The average family size is 15 persons. A clear evidence of the rural nature the household, with family labour as main source of labour.

Rice farms are of small size, 0.25 to 1.5 ha, with an average of 0.90 ha. The average output per cropping season is about 4.8 tons per hectare. The cost of production gives an average of 360 810 CFA F/ha. This cost is increased basically by the cost of fertilizer and labour which both constitute the main expenses items incurred by farmers.

Table 1: The socio-economic characteristics of farm households

Parameter	Minimum	Maximum	Mean	Standard dev
Age	24	86	49	4.56
Experience	3	40	33	7.33
Household size	3	41	15	7.85
Farm size (ha)	0.25	1.5	0.90	0.21
Production (kg/ha)	1436	7181	4816	1025
Labour (MD/ha)	193	1264	4.27	135
Seed (kg/ha)	34	137	70.78	13.86
Fertilizer (kg/ha)	50	700	370	1.01
Pesticide CFA F/ha)	1000	28000	12177	7236
Capital (CFA F/ha)	1250	282370	46016	5.7894
Cost of labour (CFA F/ha) (FC (CFA F/ha)	50245	289000	106093	32938
Fertilizer cost (CFA F/ha) (CFA F/ha)	22498	240000	110436	31643
Cost of seed (CFA F/ha) (CFA F/ha)	7524	60000	28382	6.497
Total cost (CFA F/ha)	82517	899370	303104	70674

3.2. Estimation of stochastic frontier production function

The results of the stochastic frontier production function estimation as obtained from Frontier 4.1 software are displayed in the table 2 below:

The maximum likelihood (ML) ratio test of the model is used to measure its overall fit. When the empirical value of ratio is greater than the theoretical value of the chi-square at 5% level, then we considered the model as well adjusted. Herein, the calculated value is 21.62 while the theoretical one is 9.49. Because the calculated value is superior to the theoretical value, the specified model is adequate.

Table 2: Results of the estimation of stochastic frontier production function

Variables	Coefficient	Standard error	T-ratio
Production function			
Constant	7.17***	0.72	9.5
Ln(Sup)	0.93***	0.09	10.2
Ln(MO)	0.12	0.104	1.2
Ln(K)	0.005	0.004	1.3
Ln(Fer)	0,109*	0.07	1.6
Ln(Man)	-0.003	0.003	-1.1
Ln(Pest)	-0.0008	0.006	-0.12
Technical inefficiency			
Experience	-0.08*	0.5	-1.7
Household size	0.006	0.012	0.5
Literacy	1.54*	0.97	-1.6
Other activities	-1.35	0.91	-1.5
Variance parameters			
Sigma squared (σ^2)	0.6*	0.27	2.2
Gamma (γ)	0.93***	0.04	24.21
LR	21.62***		

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

The results indicate that the coefficient of the variable « farm size » is significant at 1% significance level. A 10% increase of the cultivated land leads to about 9% increase of the total rice production. This reason is that farmers have acquired sufficient knowledge about the production process so much so that availability of farming lands has become a limiting factor to production. This result conforms to Shehu and Mshella (2007) studies about rice farmers in Nigeria. Their findings show that farm size has a positive effect and highly significant on rice production with an elasticities of 0.83 (Nigeria).

As to the use of fertilizers, a 10% increase of the quantities used would yield an increase of the production by 10.9%.

The average level of technical efficiency of producers is 80.15%, (table 3). This indicates more possibilities to increase production without increasing inputs. Indeed, these producers could increase their production by 19.85% without necessarily increasing the volume of entrants. On Bagre rice production plain, the index of technical efficiency is about 80% (Ouédraogo, 2011).

Table 3: Technical efficiency index

	N	Minimum	Maximum	Mean	Standard deviation
Technical efficiency	130	25.7	95.85	80.1475	12.84417
N valid (list-wise)	130				

Figure 1 below shows the dispersion regarding the level of producers' technical efficiency. 68% of famers are in the group of efficiency between 70% and 80%.

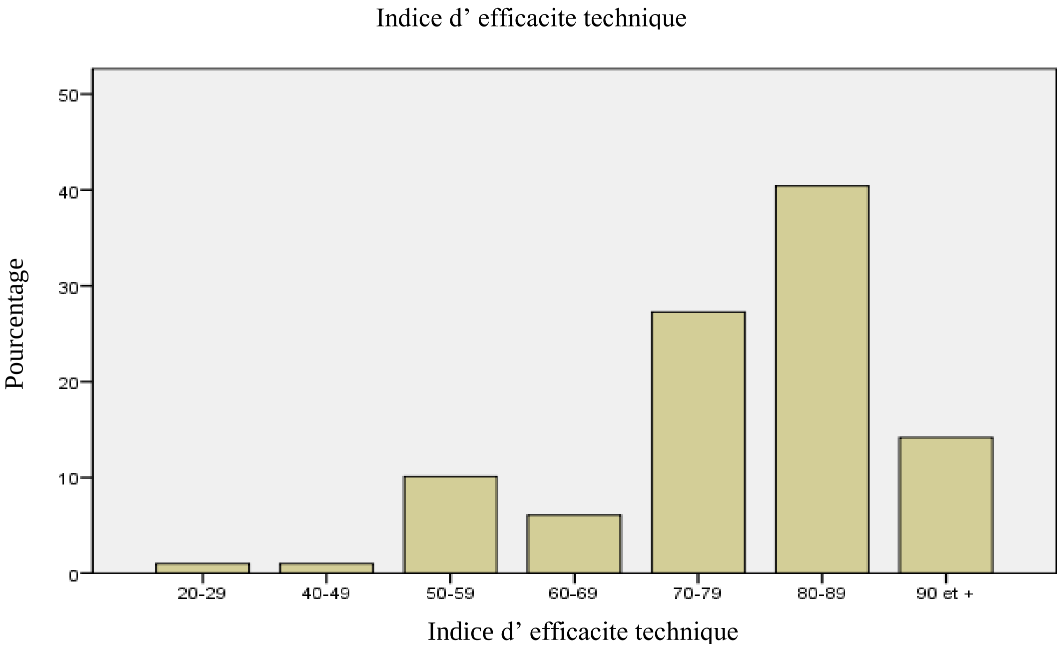

Figure 1: Graphical distribution of technical efficiency

The existence of technical inefficiency is confirmed by the gamma value, indicating that approximately 93% of the variations in the current production level are due to the difference in technical efficiency of rice farmers. The remaining 7% derive from random factors beyond the farmer's control.

Analysis of the determinants of technical efficiency of producers reveals that the coefficient of the variable experience is significant at 10% significance level. Its coefficient shows a negative sign. The implication is that the more experience the farmer gets on the plain, the less efficiently does he allocate available resources. The reason is that these farmers are most often involved with other activities other than farming while leaving production activities under the care of their children and labourers.

For the variable literacy, its coefficient is significant at 10% level. Thus, literacy positively influences the production level.

3.3. Estimation of stochastic frontier cost function

Table 4 shows the estimates values of parameters that represented the elasticity of unit cost of inputs as compared to total cost variation.

The value of LR (131.66) is above the theoretical (11.1) chi square at 5% level. This means that the model is properly specified.

Overall, we can conclude that the choice of the variables and the model specification are of some good qualities. Most coefficients are significant and relevant, with positive signs in cost formation, showing conformity with economic literature. The factors of production affect significantly the cost of production. To clearly illustrate this fact, the cost of mineral fertilizer has the most significant influence on the cost of rice production. A 10% variation of the price of mineral fertilizer would have above 3% impact on the total cost of production. Similarly, a price change of 10% of pesticides would lead to an increase of 1.4% of the total production cost.

Table 4: Results of the estimation of the cost function

Variables	Coefficients	Standard error	T-Ratio
Constant	3.7***	0.28	12.84
Y	0.12***	0.027	4.69
Labour	0.14***	0.028	5.07
Fertilizer	0.36***	0.027	13.28
Seeds	0.14***	0.027	5.2
Pesticide	0.049***	0.01	4.62
Capital	0.023***	0.006	3.77
Allocative inefficiency			
Experience	-0.0067*	0.003	-1.93
Household size	-0.057***	0.014	-3.9
Literacy	0.043	0.08	0.52
Other activities	-0.0054	0.08	-0.066
Sigma	0.1009****	0.016	6.2
Gamma	0.98***	0.007	142.6
LR	131.66		

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

The analysis of allocative efficiency determinants shows that the variable "years of experience and the household size have negative influence on the allocative efficiency of the producers. Indeed, the more experience the farmer gets on the VDK plain, the less efficiently he allocates available resources. The same situation applies when the size of the farm increases. There is a tendency for producers who have spent a lot of years in rice production to overlook new operational management training delivered by supervisors. Big farm owners make poor use of resources because of the low-level control on operational expenses.

The 0.98 value of gamma indicates that 98% of inefficiencies observed result from the poor management of resources by the producers.

Rational producers keep factors of production costs to a minimum while increasing their profits. The analysis shows that producers display an average level of allocative efficiency reaching 92.7% (table 5). This value nearing 1 is a clear indication that the units of production are 7.3% away from their maximum capabilities to better managing the available resources. Beloume (1999) came up with 83.83% of allocative efficiency index for the same producers in 1999. That is a complete improvement as compared to this year.

Table 5: Allocative efficiency index

	N	Minimum	Maximum	Mean	Standard deviation
Allocative inefficiency	130	23.45	98.71	92.7	7.79
N valid (list-wise)	130				

Figure 2 below shows a major gap on the VDK plain with minimum allocative index at 23.45% and maximum at 98.71%. Here again is an explicit corroboration for the resource management conditions on the plain. Furthermore, a large majority of producers (72%) have an index of allocative efficiency between 80 and 89%. In other words, this majority share the same factors that determine their allocative inefficiency.

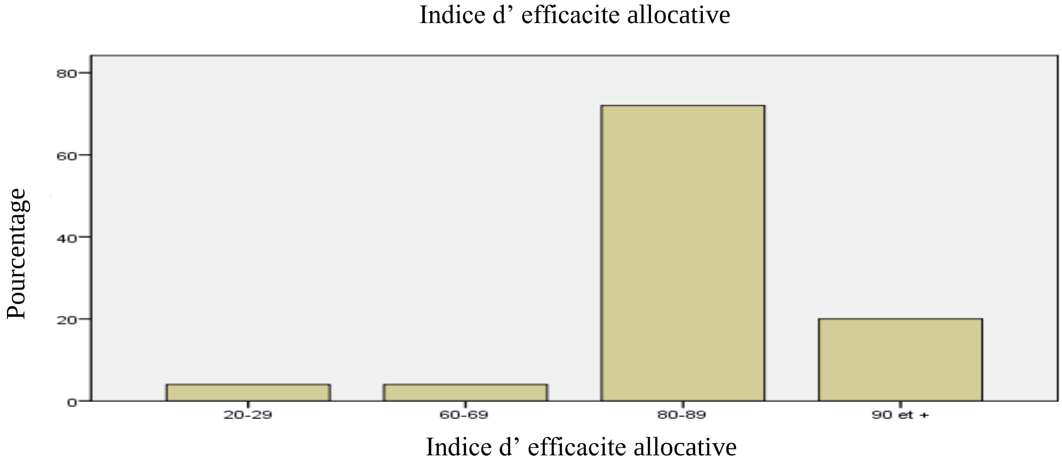

Figure 2: Graphical distribution of allocative efficiency indices

3.4. Economic efficiency calculation

The economic efficiency synthesizes the two efficiencies developed above. The economic efficiency level at the VDK is between 20.48 and 93.80, with a mean of 74.43% (table 6). Beloume (1999) came up with a value of 71.03% for this same region. In other words, in 2009, producers improved their economic efficiency level to a score of 3.4 as compared to 1999.

Table 6: Economic efficiency index

	N	Minimum	Maximum	Mean	Standard deviation
Economic efficiency (%)	130	20.48	93.8	74.43	14.08
N valid (list-wise)	130				

Figure 3 shows a huge gap between producers. Indeed, 36.2% have an economic efficiency level between 80 and 89%. More than 75% of producers' economic efficiency is above 70%. This is an evidence of potential reduction of the costs of production while keeping the same level of production by improving technical and allocative efficiencies. By efficiently allocating factors of production, there is a possibility for producers to save 25% of the resources.

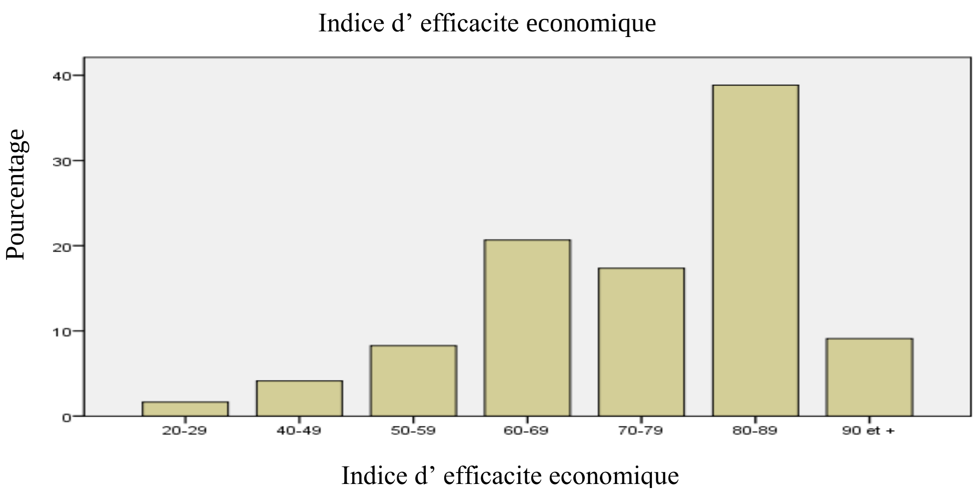

Figure 3: Graphical distribution of economic efficiency indices

4. CONCLUSION AND RECOMMENDATIONS

This paper made use of technical, allocative and economic efficiency indices to determine socio-economic factors that have influence on technical and allocative efficiencies. With regard to stochastic frontier production function, the results showed that the coefficient of variables as farm size, quantity of fertilizer used, years of experience and literacy are significant, reflecting their influence on the production level. All selected variables pertaining to cost function proved to be significant. Concerning the determinants of efficiency, the years of experience and the size of the household of an individual producer had a negative impact on their allocative efficiency. Furthermore, the evolution of technical, allocative, and economic efficiency levels reveal that the average of producers are allocatively more efficient than they are technically and economically. The 74.43% of the level of economic efficiency is an indication that producers can save up to 25% without necessarily having to reduce the level of production.

To improve the economic efficiency level of rice producers of the VDK along with their living conditions, the following steps could be taken, based on the findings of this paper:

- ✓ organize and train producers technically so as to allow them to use in a rational manner the factors of production;
- ✓ implement a policy for the extension of cultivated lands;
- ✓ provide more mineral fertilizer subsidies (the government has already showed commitment) in order for farmers to secure the required quantity of fertilizer for greater production;
- ✓ increase the educational level of producers by literacy;
- ✓ Encourage farmers to use improved seeds instead of local seeds and to diversify their activities.

References

Aigner, D. J., Lovell, C. A. K., & Schmidt, P. J. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6, 21-37.

Alliance, S. (2010). *Rice in the world.* http://www.alliancesud.ch/fr/infodoc/dossiers/riz/le-riz-dans-le-monde.

Battese, G. E., & Corra, G. S. (1977). Estimation of a production function model with applied to the pastoral zone of eastern Australia. *Austarilian Journal of Agricultural Economics*, 21, 169-179.

Battese, G. E., & Coelli, T. J. (1993). A stochastic frontier production function incorporation a model for technical efficiency effects. Australia, department of econometrics, university of New England, Working papers in *Econometrics and Applied Statistics*, 69, 22-30.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effect in stochastic frontier production for panel data. *Empirical Economics*, 20, 325-345.

Battese, G. E., Malik, S. J., & Gil, M. A. (1996). An investigation of technical inefficiencies of production of wheat farmers in four district of Pakistan. *Journal of Agricultural Economics*, 47, 37-49.

Beloume, T. (1999). *Analysis of the effectiveness of the rice Fields to the West and South-western Burkina Faso: The case of irrigated rice, Rice Lowlands and Uppland rice.* 3rd cycle thesis in economics. university of cocody. Abidjan. pp.143.

Bravo-Ureta, B. E., & Antonio, P. E. (1997). Technical, economic and allocative efficiency in peasant farming: evidence from the Dominican Republic. *The Developing Economics*, 35(1), 48-67.

Coelli, T. J. (1996). *A guide to frontier version 4.1c: A computer program for stochastic frontier production and cost function Estimation*. Mimeo, department of econometrics university of New England, Armidale.

Debreu, G. (1951). The coefficient of resource utilisation. *Econometrica,* 19, 275-292

Farrell, J. M. (1957). The measurement of productive efficiency. *Journal Royal Stat,* 506(120), part (3), 253-290.

Koopmans, T. C. (1951). *An analysis of production as an efficient combination of activities*. In T. C. Koopmans, Ed, activity analysis of production and allocation. Cowls commission for research in economics, Monograph no 13, Wiley, New York.

Meeusen, W., & J. Van, D. B. (1997). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, 18, 435-444.

Nuama, E. (2006). Measuring the technical efficiency of food crop farmers in Côte d'Ivoire. *Rural Economy*, 296(11-12), 39-53.

Ojo, S. O. (2004). Improving labour productivity and technical efficiency in food crop production: A panacea for poverty reduction in Nigeria. Food, *Agriculture and Environment,* 2(2), 227-231.

Ouédraogo, S. (2011). Technical and economic efficiency of rice production in lowland fitted Bagré (Burkina Faso): stochastic frontier approach. *In reviewing Cedres-Etudes,* 54(2), 78-91.

Shehu, J. F., & Mshella, S. I. (2007). Productivity and technical efficiency of small scale farmers in Adamawa state Nigeria. *Journal of Agriculture and Social Sciences*, 3(4), 133-136.

Thiam, A., Boris, E., & Bravo-Ureta, R. T. E. (2001). Technical efficiency in developing country agriculture a meta-analysis. *Agricultural Economics,* 25, 235-243.