REGULAR ARTICLE

TECHNICAL EFFICIENCY AND PRODUCTION RISK OF RICE FARMERS IN TOGO

Manawa AGNAZA, Akoété Ega AGBODJI*

* Correspondent author:

ABSTRACT

This paper analyzes the risks production effects on the technical efficiency of rice producers in Togo. The stochastic frontier model with flexible risk properties is considered. The cross-sectional data used are from the Fourth National Census of Agriculture (2011-2014) from which a sample of 2123 households was selected. The findings demonstrate that the translog model is the best fit for the mean output function. The study also finds that the risk production is significantly explained by the input variables such as land, seeds, fertilizers and labor. The average technical efficiency is 79.72%. Exogenous variables such as gender, age, experience, household size, number of fields and landownership improve the technical efficiency of rice producers in Togo. The study recommends to the Togolese Government: (i) raise the price of rice to make rice production more attractive, (ii) further subsidize input prices to ensure that they are easily accessible and affordable to producers, and (iii) organize training sessions on the best use of modern capital.

Keywords: *Technical efficiency; Production risk; stochastic frontier; rice; Togo*
JEL: C21 ; D18 ; O13 ; Q12 ; Q18

INTRODUCTION

In almost any production process, particularly in agriculture, risk plays an important role in producers' input allocation and production decisions (**Asche and Tveteras, 1999; Bokusheva and Hockmann, 2006; Kumbhakar, 2002; Nuama, 2006; Villano *et al.*, 2005**). However, farmers' input allocation decisions vary depending on the production risk they incur. They tend to reduce the allocation of an input if it potentially leads to an increase in production risk. In other words, farmers increase allocations of inputs that they deem capable of reducing production risk (**Mamilianti *et al.*, 2019**). The concept of risk in production theory is first explained by the uncertainty linked to product prices and, secondly, by the instability of production. The risk associated with production instability is generally explained by the factors used by the producer in the production process. The quantities of inputs that determine the volume of production are also responsible for the variability of production (**Kumbhakar and Tsionas, 2010; Ngom *et al*., 2016**). Indeed, some inputs can reduce production risk while others can increase production risk (**Asche and Tveteras, 1999; Just and Pope, 1978**). Thus, a farmer averse to production risks may be reluctant to adopt a new technology that could reduce the risk of production (**Ali, 2019; Just and Pope, 1978; Pope and Kramer, 1979**).

The technical efficiency of farmers is often influenced by exogenous variables that characterize the environment in which the production takes place, such as factors affecting production risk (**Villano and Fleming, 2006**). In Togo as everywhere else, given a number of hazards over which rice farmers have no control (climatic hazard for example), they cannot know with certainty the quantities of rice they will be able to produce. According to the Ministry of Agriculture, Livestock and Fisheries (**MAEP, 2010**), Togolese rice farmers produce below the national average (1 ton / hectare < 2.4 tons / hectare) due to their low productive capacity (inefficiency). In order to achieve much more relevant results, the method of analysis proposed for this study is consistent with model developed by **Kumbhakar (2002)** which allows for production risk and technical inefficiency to be estimated simultaneously in the stochastic frontier analysis. This simultaneous analysis of production risk and technical efficiency has not been fully addressed in Togo. Thus, the results of this study could contribute to the formulation of good policies on rice production in a context of production risks.

The agricultural sector employs 60% of the working population in West Africa although it contributes only 35% to GDP (**Abdulai *et al*., 2013**). The countries of this region are particularly vulnerable to climate change since people are highly dependent on rain-fed agriculture (**Gemenne *et al*., 2017**). According to studies conducted by the Food and Agriculture Organization of the United Nations (FAO) on disaster risk strategies and management in West Africa and the Sahel (2011-2013), about 65% of the West African and Sahelian working population belong to the agricultural sector and are subject to climate change and environmental factors. The main abiotic and biotic stresses encountered in their fields are weeds, birds, poor soils, floods, drought, plant diseases and insects. By 2100, the estimated losses on the agricultural sector due to climate change will vary between 2 and 4% of the sub-regional Gross Domestic Product (GDP) (**FAO, 2011**). Agriculture is the engine of Togo's economic and social development. It employs 96% of rural households with nearly 54% of the active population. It contributes about 40% to the Gross Domestic Product (GDP). It is mainly characterized by low use of improved seeds (14.9%) and chemical fertilizers (117 kg/ha compared to normally 150 kg/ha); a weak technical framework for the agricultural working population; low agricultural mechanization (high use of manual agricultural tools such as hoe, cutter); limited access to agricultural credit; etc. (Ministry of Agriculture, Livestock and Fisheries and the Directorate of Agricultural Statistics, Informatics and Documentation (**MAEP and DSID, 2014**)). However, most of the Togolese population is active around rain-fed agriculture, which is very sensitive to climate change and the various aggressions of predators. Indeed, in 2013, due to drought throughout the territory, the GDP of the agricultural sector fell by 4.8% compared to 2012 as shown in Figure 1 below (**MAEP and DSID, 2014).**

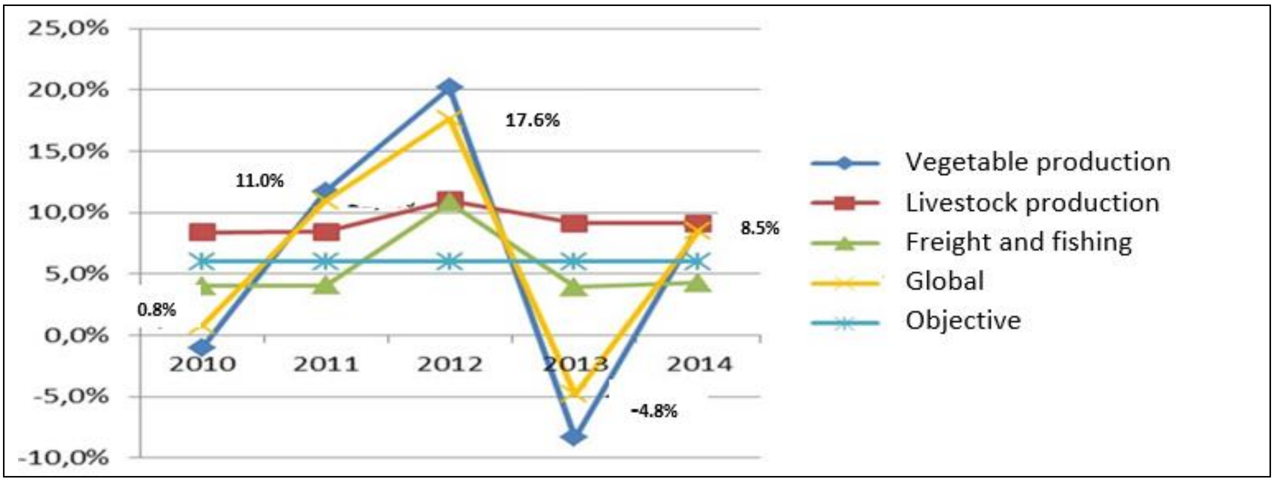

Figure 1 Annual growth rate of the GDP of the agricultural sector
Source: MAEP and DSID, 2014

As part of the revival of agricultural production, Togo has prioritized in its objectives, the development of food crops with particular emphasis on rice cultivation, which causes significant foreign exchange outflows. Indeed, ranked third as a consumer product after maize and sorghum, rice produced in Togo covers barely 50% of the country's needs and the deficit is still met by imports estimated at more than four billion CFA francs / year (**MAEP, 2010**). According to studies carried out by the Network of Peasant organizations and producers of West Africa (**ROPPA, 2016**), with the exception of the period 1996 to 1998 when national rice production exceeded imports, Togo was dependent on the rest of the world for rice demand over the period from 1995 to 2012 (see Fig.2 below).

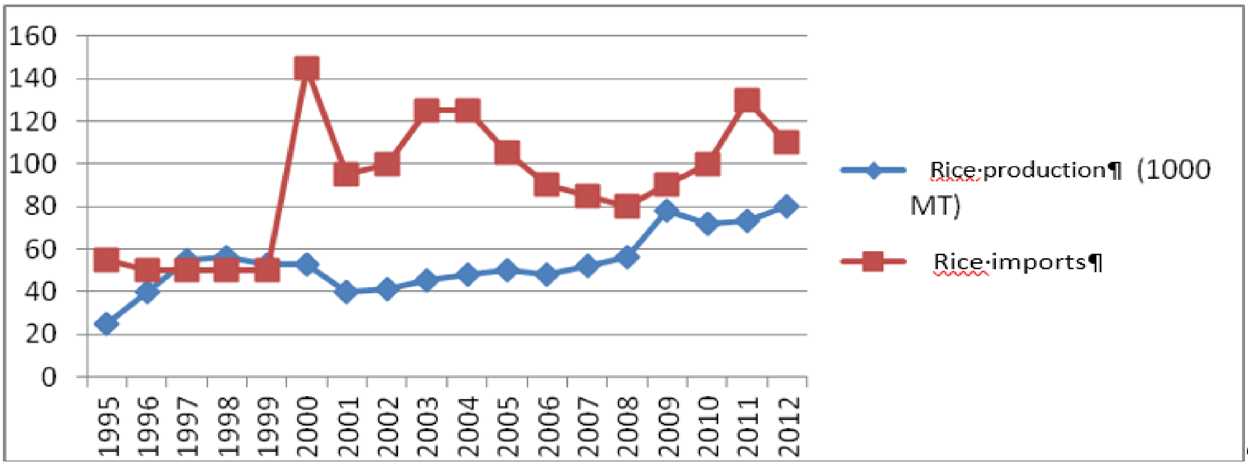

Figure 2 Evolution of rice production and imports in Togo
Source: ROPPA, 2016, p.15

In Togo, depending on the locality, rice is produced by both men and women on small individual farms. Indeed, three ecotypes of rice stand out in Togo: rainfed rice practiced mainly on emerging land from water in the Plateaux Region, represents 10% of national production, lowland rice which is by far the most cultivated represents 60% of national production and practiced in all regions of the country, in the shallows, rice produced without water control and irrigated rice practice on developed perimeters represents 30% of national production. In all these ecologies, various improved varieties of rice are grown but the most important are IR841, TGR and NERICA (Togolese Institute of Agronomic Research, the Directorate of Agricultural Statistics, Informatics and Documentation and the Africa Rice Center (**ITRA, DSID and AfricaRice, 2014**)). Rice farms in Togo are subject to a range of agricultural production risks. These include climatic risks of drought, flooding, insufficient rainfall, risks of developing a disease or attacking a crop pest, etc. Beyond these agricultural production risks, one can cite the socio-economic constraints generally related to the factors and means of production (land, seeds, labor, fertilizers, credit, equipment), post-harvest management and the rice products marketing (**ITRA, DSID and AfricaRice, 2014**). In view of all these characteristics of Togolese rice production, this study seeks to answer the following questions: Do production risks not affecting rice farms in Togo? Do Togolese rice farmers make optimal use of the factors of production mainly in a context of production risks? The main objective of this article is to analyze the effects of production risks on the technical efficiency of rice producers in Togo. Specifically, in this context of production risk, it is a question of determining: (i) the effects of production risk factors and (ii) the levels of technical efficiency of rice farmers. This study will help agricultural policy decision-makers to stimulate rice production in Togo and effectively reduce the adverse effects of production risks.

MATERIALS AND METHOD

Theorical Framework

Majority of the application of frontier methodology in efficiency analysis utilize non-parametric or parametric approaches. The two methods have a range of advantages and disadvantages, which may influence the choice of methods in a particular application. The non-parametric frontier technique which has conventionally been assimilated into the Data Envelopment Analysis (DEA) was developed by **Farrell (1957) and Charnes *et al*., (1978)**. The major advantage of the non-parametric frontier analysis is that it does not require the specification of a particular functional form for the technology. The main disadvantage is that it is not possible to estimate parameters for the model and hence impossible to test hypothesis concerning the performance of the model. The parametric frontier analysis which is the Stochastic Frontier Production Function (SFPF) was independently proposed by **Aigner *et al*., (1977)** and **Meeusen** and **Broeck (1977)**. The principal advantage of parametric frontier analysis is that it allows the test of hypothesis concerning the goodness of fit of the model. The major disadvantage is that it requires specification of technology, which may be restrictive in most cases **(Ajibefun, 2008).** Furthermore, the parametric frontier analysis proposes the inputs have similar effect on mean and variance of output. Therefore, if an input influences output positively, it is expected to influence output variance positively and vice versa (**Oppong *et al*., 2016**). But, **Just and Pope (1978)**, production function proposes a separate effect of the inputs on the mean output and the variance of output or output risk. However, this model does not take into account the technical inefficiency of producers in the production process (**Battese et al., 1997; Kumbhakar, 2002; Love and Buccola, 1991; Onumah *et al*., 2010**).
Following **Kumbhakar (2002),** the production process is represented below as Eq. (1):

$$Y_i = f(x_i;\ \beta) + g(x_i;\ \psi)v_i - q(z_i;\delta)u_i \qquad (1)$$

Y_i refers to the observed ouput produced by the i-th farm, $f(x_i;\ \beta)$ is the deterministic output function, $g(x_i;\ \psi)$ is the output risk function, ψ are the estimated coefficients of production risk function, are the input variables, x_i are the input variables, β are the estimated coefficients of the mean output function, $q(z_i;\ \delta)$ represents the technical inefficiency model, δ are the estimated effect of the explanatory variables in the technical inefficiency model, v_i represents the random noise in the data, representing production risk and u_i represents farm specific technical inefficiencies. Technical efficiency of the i-th farm is the ratio of observed output given the values of its inputs and its inefficiency effects to corresponding maximum feasible output if there were no inefficiency effects (**Battese and Coelli, 1988, p.390 in Adinku *et al*., 2013, p.42**).

The technical efficiency of the i-th farm is given by Eq. (2):

$$TE_i = \frac{E(Y_i / x_i, u_i)}{E(Y_i / u_i = 0)} = \frac{f(x_i;\alpha) - g_i(x_i;\beta)u_i}{f(x_i;\alpha)} = 1 - \frac{g_i(x_i;\beta)u_i}{f(x_i;\alpha)} \qquad (2)$$

The technical inefficiency (TI) is given by Eq. (3):

$$TI_i = \frac{g_i(x_i;\beta)u_i}{f(x_i;\alpha)} \qquad (3)$$

The technical efficiency becomes (Eq. 4):

$$TE_i = 1 - TI_i \qquad (4)$$

The variance of output or production risk is given by Eq. (5):

$$Var(Y_i/x_i, u_i) = g^2(x_i;\ \psi) \qquad (5)$$

The marginal effect of the input variables on the production risk is given by Eq. (6):

$$\frac{\partial V(Y)}{\partial x_j} = \frac{\partial g^2(x,\psi)}{\partial x_j} = 2g(x,\psi)g_j(x,\psi) \quad (6)$$

Thus,

$\frac{\partial g^2(x,\psi)}{\partial x_j} < 0 \Rightarrow$ Risk decreasing of the j'th input,

$\frac{\partial g^2(x,\psi)}{\partial x_j} = 0 \Rightarrow$ Risk neutral of the j'th input and

$\frac{\partial g^2(x,\psi)}{\partial x_j} > 0 \Rightarrow$ Risk increasing of the j'th input.

Based on the assumptions of the random errors a log likelihood function for the observed farm output is parameterized in terms of $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \frac{\sigma_u^2}{\sigma_v^2}$ (**Aigner *et al.*, (1977)**. However, this parameterization has a limitation since the variance, ${\sigma_u}^2$ refers to the variance of the untruncated random variable instead of the truncated half normal model (**Adinku *et al.*, 2013, p.28**). A different parametrization proposed by **Battese and Corra (1977, p.171)** helps solve the above problem. This new specification is given by Eq. (7):

$$\gamma = \frac{\sigma_u^2}{\sigma^2} = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \quad (7)$$

Where σ^2 and γ are the variance parameters. The maximization of the appropriate log likelihood function gives the estimates of the model. For $0 < \gamma < 1$, the output variability is characterized by technical inefficiency and stochastic errors. γ measure the level of the inefficiency in the variance parameter (σ^2).

Empirical Model Specification

The empirical application of this study is consistent with model developed by **Kumbhakar (2002)** which allows for production risk and technical inefficiency to be estimated simultaneously in the stochastic frontier analysis. However, there are generally two functional forms of the stochastic frontier model that are often used; the Cobb-Douglas and the translog functional forms (**Adinku *et al.*, 2013, p.44**). In this study, the translog model of the production function is used and specified as Eq. (8):

$$\ln Y_i = \beta_0 + \sum_{i=1}^{5} \beta_j \ln x_{ij} + \frac{1}{2}\sum_{i=1}^{5}\sum_{k=1}^{5} \beta_{jk} \ln x_{ij} \ln x_{ki} + \varepsilon_i \quad (8)$$

β_j denotes the unknown true values of the technology parameters. If, β_{jk} = 0 then the translog stochastic frontier model reduces to the Cobb-Douglas model. The composed error term is given as Eq. (9):

$$\varepsilon_i = g(x_i;\ \psi) - q(x_i;\ z_i) \quad (9)$$

$g(x_i;\ \psi)$ is the risk component and $q(x_i;\ z_i)$ is the technical inefficiency component.

Elasticity

The elasticities of output with respect to the different inputs are functions of the level of inputs involved and generally expressed as Eq. (10):

$$\frac{\partial LnE(Y_i)}{\partial \ln x_{ji}} = \{\beta_j + \beta_{jj} Lnx_{ji} + \sum_{k\neq 1} \beta_{jk} \ln x_{ki}\} \quad (10)$$

However, when the output and input variables have been normalized by the respective sample means, the first-order coefficient can be interpreted as elasticities of output with respect to the different input (**Onumah *et al.*, 2010**). For this study, the output and input variables have been normalized using the standardized mean method, the first-order coefficients of the input variables can therefore be interpreted as elasticities of output. The sum total of the output elasticities is the estimated scale elasticity (Ɛ), which is defines as the percentage change in output as a result of 1 percent change in all input factors. Scale elasticities greater than one indicates an increasing returns to scale. An estimate less than one indicates a decreasing returns to scale, whiles an estimate equal to one indicates a constant return to scale (**Khreisat, 2011**). The input variables used in this study are land, seed, fertilizer, labor and modern capital (Table 1).

Table 1 Variable Description of the Input Variables in the Rice Production Process

Variable	Variable Description	Measurement
Y_i	Output	Kilograms (kg).
x_{1i}	Land	Hectare (ha).
x_{2i}	Seed	Kilograms (kg).
x_{3i}	Fertilizer	Kilograms (kg).
x_{4i}	Labor	Number of people per day on the rice farm
x_{5i}	Modern capital	Dummy, 1 assigned to farmers who used a tractor, hitched or motorized harrow, plough and 0 otherwise.

Production risk

The linear production risk function is specified as Eq. (11):

$$g(x_i\,;\psi)v_i = \psi_0 + \sum_{m=1}^{5}\psi_m\, x_{mi} \quad (11)$$

Where x_i's represent the input variables, ψ are the estimated risk model parameters and the v_i's are the pure noise effects. x_{1i} denotes land measured in hectare, x_{2i} denotes seed measured in kilograms, x_{3i} denotes fertilizer measured in kilograms, x_{4i} denotes labor measured in number of people per day on the rice farm, x_{5i} denotes modern capital measured as a dummy, 1 assigned to farmers who used a tractor, hitched or motorized harrow, plough and 0 otherwise. $\psi_{m's}$ are the marginal production risks of the individual inputs and if it is positive it means that the respective input is a risk increasing input. If it is negative it means that respective input reduces output variance.

Technical Inefficiency

The linear technical inefficiency model is given as Eq. (12):

$$q(z_i\,;\delta_i) = \delta_0 + \sum_{j=1}^{15}\delta_n\, z_{ni} \quad (12)$$

where z_i's are the exogenous explanatory variables and the δ_i's are the estimated coefficients of the technical inefficiency model. The exogenous variables used in this study are gender, age, educational level, Experience, household size, number of fields, main activity of the farmer, Member of a farmer based organization, extension visit, credit access, landownership and regional effects (Table 2).

Table 2 Description of Exogenous Variables

Variable	Variable Description	Measurement
z_1	Gender	1= Male, 0 = Female
z_2	Age	Years
z_3	Educational Level	None = 0 Literate (A person who has just learned to write and speak French) = 1 Primary level = 2 Middle School = 3 High school = 4 University level = 5 Vocational level = 6
z_4	Experience	Number of years that the farmer has been engaged in rice farming.
z_5	Household size	Number of people (men, women and children) who are living with the farmer during the cropping year.
z_6	Number of fields	Total number of plots that can be delimited on the holding.
z_7	Main activity of the farmer	1= Agriculture, 0 = otherwise
z_8	Member of a farmer based organization	1= Yes, 0 =No
z_9	Extension visit	1= farmers who had interactions with the extension agent during the production year to solicit for advice, 0 = No
z_{10}	Credit Access	1 = farmer had access to credit, 0 = No
z_{11}	Landownership	1= farmer owns his farm, 0 = farmer

		operating on a rented land.
z_{12}	Plateaux Region	1 = Yes, 0 = otherwise
z_{13}	Central Region	1 = Yes, 0 = otherwise
z_{14}	Kara Region	1 = Yes, 0 = otherwise
z_{15}	Savannah Region	1 = Yes, 0 = otherwise

Statement of Hypothesis
The following hypothesis were considered for investigation.

H_0: $\beta_{jk} = 0$, the coefficients of the second-order variable in the Translog model are zero. This implies that the Cobb-Douglas function is the best fit for the model.

H_0: $\Psi_1 = \Psi_2 ... = \Psi_5 = 0$, the null hypothesis that output variability is not explained by production risk in input factors.

H_0: $\lambda = 0$, the null hypothesis specifies that inefficiency effects are absent from the model at every level. The variance of the inefficiency term is zero; the exogenous factors should be incorporated into the mean output function and estimated using ordinary Least Square. However, if $\lambda > 0$, it means that the technical inefficiency effects are present in the model and hence the stochastic frontier model must be employed.

H_0: $\delta_1 = \delta_2 = ... = \delta_{15} = 0$, the null hypothesis that exogenous variables do not account for technical inefficiency.

H_0: $\delta_{12} = \delta_{13} = \delta_{14}\ \delta_{15} = 0$, the null hypothesis that there are no regional effects on technical efficiency of production.

$H_0 : \overline{X}_A = \overline{X}_B$, the null hypothesis that mean technical efficiency for Region A is the same as that of Region B.

Where:
If $\bar{X}_A$ is the mean technical efficiency of rice producers in Savanes Région, $\bar{X}_B$ is the mean technical efficiency of rice producers in Kara or Centrale or Plateaux or Maritime Region.
If $\bar{X}_A$ is the mean technical efficiency of rice producers in Kara Région, $\bar{X}_B$ is the mean technical efficiency of rice producers in Centrale or Plateaux or Maritime Region.
If $\bar{X}_A$ is the mean technical efficiency of rice producers in Centrale Région, $\bar{X}_B$ is the mean technical efficiency of rice producers in Plateaux or Maritime Region.
If $\bar{X}_A$ is the mean technical efficiency of rice producers in Plateaux Région, $\bar{X}_B$ is the mean technical efficiency of rice producers in Maritime Region.

The entire hypothesis with the exception of the sixth one (i.e. the difference in mean technical efficiency) was investigated using the generalized likelihood-ratio statistic (LR) which is given by Eq. (13):

$$LR = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \quad (13)$$

Where:$L(H_0)$ and $L(H_1)$ are values of likelihood function under the null (H_0) and alternative (H_1) hypothesis, respectively. LR has approximately a Chi-square distribution if the given null hypothesis is true with a degree of freedom equal to the number of parameters assumed to be zero in (H_0). The third hypothesis however assumes a mixed Chi-square distribution hence Table 1 of **Kodde and Palm (1986, p.1246)** is used. The difference in mean technical efficiency is investigated using a t-test.

Data sources
This study used cross-sectional data from the Fourth National Census of Agriculture of Togo (4^{th} RNA, 2011 – 2014). These survey data were carried out by the Agricultural Statistics Directorate (DSID) and Agricultural Ministry (MAEP) of Togo following the modular approach advocated by FAO. At the end, 217396 rice producers were identified throughout the whole country and distributed as follows: 5540 for the Maritime region, 72260 for the Plateaux region, 29342 for the Central region, 46546 for the Kara region and 63708 for the Savanes region. However, households with missing information are eliminated from the study data. This reduces the sample size to 2123 rice producers distributed as follows: Maritime region (105), Plateaux region (423), Central region (275), Kara region (463) and Savannah region (857).

RESULTS AND DISCUSION

Summary Statistics of the Output and the Input

The average production of rice producers in the study area is 969.70 kg. This is lower than the national average which is 2.4 tons/ha (**MAEP, 2010**). The average lands rice cultivated are less than one hectare (0.53 ha). The rice producers in the study area use an average of 13.71 kg of seed, among which we most often have IR841, TGR and NERICA. They also use different combinations of fertilizers such as NPK 15.15.15, organic fertilizers and Urea for rice production. The average amount of fertilizer used is 103.48 kg. In terms of labor, an average of 3 people per day work on each producer's farm (Table 3).

Table 3 Summary statistics of the output and input variables

Variables	Mean	Standard Deviation	Minimum	Maximum
Output (kg)	969,70	3661,20	25	104247
Land (ha)	0,53	1,84	0,01	51,89
Seed (kg)	13,71	19,75	3	500
Fertilizer (kg)	103,48	543,56	10	13620
Labor (Man-days)	3,12	2,17	1	28

Source: Authors based on the Fourth National Census of Agriculture data, Togo.

Statistical description of socioeconomic and demographic quantitative variables

The heads of households in the study area are on average 45 years old and have an average of almost 9 years of experience in the field of rice production. The average household size is 7 people. The total number of fields on all farms is on average 6 (Table 4).

Table 4 Descriptive statistics of demographic and socioeconomic characteristics of farmers

Variables	Mean	Standard Deviation	Minimum	Maximum
Age (Years)	44,56	14,53	18	85
Experience (Year)	9,22	8,55	1	61
Household size (Number of people in the farmer household)	7,24	4,22	1	45
Number of fields (total number of plots)	5,86	4,01	1	20

Source: Authors based on the Fourth National Census of Agriculture data, Togo.

Statistical description of qualitative production and socioeconomic and demographic variables

According to table 5 below, only 16% of the farmers used the modern capital (tractor, hitched or motorized harrow, plough). This low proportion can be explained by the lack of financial means or by excessively high costs of modern capital. Rice farms are largely marked by a strong male predominance (90%) against only 10% for women. This can be justified by the fact that most of the land used by women is largely ceded by their husbands. Men would have more access to land than women. The distribution of producers in the study area according to level of education is as follows: 47.9% of producers have no level of education; 3.63% are literate; 25.34% reached the Primary level; 17.62% reached the Middle school; 3.96% reached the High school; 0.8% have reached the University school and 0.75% have followed vocational training in agriculture. Agriculture is the predominant activity of nearly 70% of farmers. A small proportion (7%) of farmers are members of an agricultural association or group. Thus, the low proportions of 4 and 3% respectively of participation of farmers with extension agents and access to agricultural credits can be explained by low participation of farmers in agricultural organizations. The producers who own the cultivated lands are on average 36%. Finally, only 5% of farmers in the study areas are from the Maritime region, 20% from the Plateaux region, 13% from the Central region, 22% from the Kara region and 40% from the Savanes region.

Table 5 Descriptive statistics of qualitative production and socioeconomic and demographic variables

Variables	Frequency (%)
Modern capital (1 = if use tractor, hitched or motorized harrow, plough)	16
Gender (1= Male)	90
Educational Level:	
None = 0	47.9
Literate (A person who has just learned to write and speak French) = 1	3.63

	Primary level = 2	25.34
	Middle school = 3	17.62
	High school = 4	3.96
	University level = 5	0.8
	Vocational level = 6	0.75
Main activity (1= Agriculture)		70
Member of a farmer based organization (1= Yes)		7
Extension visit (1= Yes)		4
Credit Access (Access to credit = 1)		3
Landownership (Own land = 1)		36

Source: Authors based on the Fourth National Census of Agriculture data, Togo.

Testing of hypothesis

Results of the various hypothesis tested are presented in Table 6. Hypotheses 1, 2, 3, 4 and 5 are rejected at 0.01 level of significance. This implies respectively that, (i) the translog model is an adequate representation of the data than the Cobb-Douglas model. (ii) The variability of rice production is explained by production risk in input variables. (iii) The variation in the observed output from the frontier output is due to technical inefficiency and random noise. From Table 7 it is observed that the estimated lambda is 2.627 and it is significantly greater than zero. This implies that variation in output explained by technical inefficiency is relatively larger than the deviations in output from pure noise component of the composed error term. This makes the stochastic model a better model than the deterministic frontier. Gamma ($\gamma = 0.8735$) which is also a measure of the level of the inefficiency in the variance parameter is significant at 1 percent indicating that 87 percent of the total variations in rice output are due to technical inefficiencies in the study area. (iv) The technical inefficiencies are explained by exogenous variables. (v) There are regional effects on technical efficiency of production.

Table 6 Results of hypothesis test

Null Hypothesis	Test Statistic (λ)	Critical value (λ^2)	Decision
H_0: $\beta_{jk} = 0$	280,51***	30,58	Reject H_0
H_0: $\Psi_1 = \Psi_2 ... = \Psi_5 = 0$	181,73***	15,09	Reject H_0
H_0: $\lambda = 0$	802,31***	5,412	Reject H_0
H_0: $\delta_1 = \delta_2 = ... = \delta_{15} = 0$	2301,02***	30,58	Reject H_0
H_0: $\delta_{12} = \delta_{13} = \delta_{14}\ \delta_{15} = 0$	2138,53***	13,23	Reject H_0

Source: Authors computations. ***, indicate 1%, level of significance. The critical value of the third hypothesis was obtained from Table 1 of **Kodde and Palm (1986).**

Elasticity of production and returns to scale

The output elasticities based on estimates of the mean output function (Table 7) are presented in Table 8.

Table 7 Maximum likelihood estimates of the Translog Mean Output Function

Variables	Parameters	Estimates	Standard Errors
Constant	β_0	0,155***	0,003
Ln(Land)	β_1	1,002***	0,002
Ln(Seed)	β_2	0,011***	0,003
Ln(Fertilizer)	β_3	-0,005**	0,002
Ln(Labor)	β_4	0,003	0,004
Modern capital	β_5	-0,003**	0,001
0.5 x [Ln(Land)] ^{2}	β_6	0,006***	0,002
0.5 x [Ln(Seed)] ^{2}	β_7	-0.013***	0,004
0.5 x [Ln(Fertilizer)] ^{2}	β_8	0,004**	0,002
0.5 x [Ln(Labor)] ^{2}	β_9	0,014***	0,005
0.5 x (Modern capital) ^{2}	β_{10}	-0,001*	0,000
Ln(Land) x Ln(Seed)	β_{11}	0,000	0,002
Ln(Land) x Ln(Fertil)	β_{12}	-0,002	0,001

Ln(Land) x Ln(Labor)	β_{13}	0,002	0,002
Ln(Land) x CapMod	β_{14}	-0,001	0,001
Ln(Seed) x Ln(Fertil)	β_{15}	0,007***	0,002
Ln(Seed) x Ln(Labor)	β_{16}	-0,004	0,003
Ln(Seed) x CapMod	β_{17}	-0,001	0,001
Ln(Fertil) x Ln(Labor)	β_{18}	-0,001	0,003
Ln(Fertil) x CapMod	β_{19}	-0,000	0,001
Ln(Labor) x CapMod	β_{20}	-0,002*	0,001
Variance parameters			
Sigma_u		0,108	0,003
Sigma_v		0,041	0,002
Lambda (λ=)σ_u/σ_v		2,627	0,004
Sigma-square ($\sigma^2 = \sigma^2{}_u + \sigma^2{}_v$)		0,013	0,001
Gamma ($\gamma = \sigma^2{}_u/\sigma^2$)		0,874	

Source: Authors computations. ***, **, *, indicate 1%, 5%, and 10% level of significance respectively

However, the discussion of the parameters of the mean output function are based on output elasticities (Table 8).

Table 8 Elasticity of Production and Returns to Scale

Variables	Elasticity
Land	1,002***
Seed	0,011***
Fertilizer	-0,005**
Labor	0,003
Modern capital	-0,003**
Returns to Scale (RTS)	1,01

Source: Authors computations. ***, **, indicate 1%, and 5% level of significance respectively

An increase of 1% in land leads to 1.002% increase in production. Compared to other elasticities, we can say that the increase in rice production in Togo depends largely on the land. This result is also reflected in studies conducted by **Villano and Fleming (2006)** and **Tran (2019)**. As for the work of **Tiedemann and Latacz-Lohmann (2013)** and **Oppong *et al.*, (2016),** the land is positively related to average production. A 1% increase in the quantities of seeds used leads to an increase in production of 0.011%. As in the papers of **Adinku *et al.*, (2013), Kara *et al.*, (2019)** and **Oppong *et al.*, (2016)**, we can say that the optimal amounts of seeds used by Togolese rice farmers are not yet reached. The small positive effect is explained by the high use (85.1%) of traditional seeds (MAEP and DSID, 2013). The negative effects of production variables such as the quantities of fertilizers used and the use of modern capital are unexpected in the context of this study. Indeed, we admit with **Kaboré (2007)** that the quantities of fertilizers used tend to increase yields by improving soil fertility. Also, it is noted in **Fontan (2008)** that a misuse or control of modern capital due to a lack of training would lead to a reduction in production.

The return to scale is increasing because the sum of the partial elasticities of production is equal to 1.01 > 1. Indeed, the constant return to scale test rejects the null hypothesis thus reflecting the lack of uniqueness of the sum of the partial elasticities (LRcalculated = 159.87 > LRlu = 6.63). This implies that a simultaneous increase of 1% of all inputs used in the production process leads to an increase in production of 1.01%.

Estimates of marginal output risk

The estimates for the marginal input risk are presented in Table 9.

Table 9 Maximum Likelihood Estimates of the Linear Production Risk Function

Variables	Parameters	Estimates	Standard Errors	P > [z]
Constant	Ψ_0	-6,490***	0,096	0,000
Land	Ψ_1	-0,109*	0,057	0,056
Seed	Ψ_2	-0,622***	0,096	0,000
Fertilizer	Ψ_3	0,457***	0,085	0,000

Labor	Ψ_4	-0,737***	0,227	0,001
Modern capital	Ψ_5	-0,056	0,035	0,115

Source: Authors computations. ***, * indicate 1%, and 10% level of significance respectively

A 1% increase in the land leads to a reduction in production risks of 0.11%. Togolese rice farmers would become more involved in their production activities as they increase their land. On the other hand, for **Battese *et al*., (1997) and Guttormsen and Roll (2013)**, any increase in the land would lead to a reduction in working time per square meter. This leads to a reduction in productive capacity and thus to a decrease in production. For **Oppong *et al*., (2016),** the larger the land, the more it is exposed to effects of adverse weather conditions at harvest or planting times.

An increase of 1% in the amount of seed used leads to a reduction in production risks of 0.62%. The seeds used by Togolese rice farmers would be resistant to climatic hazards, plant diseases and would also be adapted to their production environment. This result is consistent with that of the study conducted by **Guttormsen and Roll (2013)**. For the latter, the use of improved seeds adapted to the production environment leads to less variation in the quantity and quality of the crop produced. On the other hand, for **Picazo-Tadeo and Wall (2011)** the quantities of seeds used by Spanish rice farmers increase the risk of production. A 1% increase in the amount of labor leads to a reduction in production risks of 0.74%. This implies that Togo rice farmers would have a good quality of used labor. Beyond this, a good quality of the labor would lead to an increase in the producer's ability to cope with the negative effects of rainfall instability (ease of setting up irrigation systems, better monitoring and maintenance of the crop for example). This result is similar to the analysis conducted by **Kara *et al*., (2019).** In **Adinku *et al.*, (2013),** a use of labor beyond the optimal level per hectare may lead to a decrease in production and thus an increase in the variability of production.

A 1% increase in the amounts of fertilizer used leads to an increase in production variability of 0.46%. The quantities of fertilizers used by Togolese rice farmers would be of poor quality. It may be of good quality but with levels of use too low or too high compared to the optimal level. This result is consistent with the study of **Bokusheva and Hockmann (2006).** However, the results of **Adinku et al., (2013)** and **Kara *et al*., (2019)** shows a reduction in production risks of 0.824% and 0.3468% respectively given an increase of 1% in the amount of fertilizers.

Technical Efficiency Estimates

The estimates of the parameters for the determinants of inefficiency are presented in Table 10.

Table 10 Maximum Likelihood Estimates of the Technical Inefficiency Model

Variables	Parameters	Estimates	Standard Errors	P > [z]
Constant	δ_0	-1,615***	0,172	0,000
Gender	δ_1	-0.318***	0,103	0,002
Age	δ_2	-0.006***	0,002	0,009
Education	δ_3	0,112***	0,024	0,000
Experience	δ_4	-0,008**	0,003	0,025
Household Size	δ_5	-0,016**	0,008	0,028
Number of fields	δ_6	-0,013*	0,008	0,083
Main occupation	δ_7	0,194***	0,070	0,005
Member of a farmer based organization	δ_8	0,017	0,173	0,924
Extension visits	δ_9	0,041	0,214	0,850
Credit Access	δ_{10}	-0,356	0,240	0,138
Landownership	δ_{11}	-0.626***	0,065	0,000
Plateaux Region	δ_{12}	2,134***	0,173	0,000
Central Region	δ_{13}	-37,485	1203,503	0,975
Kara Region	δ_{14}	0,996***	0,175	0,000
Savannah Region	δ_{15}	-1 459***	0,182	0,000

Source: Authors computations. ***, **, *, indicate 1%, 5%, and 10% level of significance respectively

The expected result of the coefficient of the gender variable, which reflects the fact that the male producer would be technically more efficient than the female producer, is verified. This coefficient is -0.318 and significant at 1%. This result is consistent with **Kibaara's (2005)** conclusion that male rice farmers would be physically better able to engage in agricultural activity, they would have more access to agricultural credit and would attend more agricultural extension seminars and thus, would probably reduce their technical inefficiency. The expected effect of the age variable which states according to **Adinku *et al*., (2013)** that older producers would be technically less efficient than younger is confirmed with negative effect equal to -0.006, and is significant at 1% on the technical inefficiency. Conversely, **Coelli and Battese (1996)**, stated that, age could have a positive or negative effect on technical inefficiency. Older producers may be more traditional and conservative and therefore less willing to adopt best agricultural practices.

The positive (0.112) and significant effect of the educational level variable on technical inefficiency is unexpected in this study. Indeed, in accordance with **Battese and Coelli (1995),** the level of education is supposed to increase farmers' capacities on the use of existing modern technologies and thus improve their levels of efficiency. However, for **Owour and Shem (2009),** educational attainment is negatively correlated with the technical efficiency of farmers. One explanation is that technical skills in agricultural activities especially in developing countries are influenced more by practical training in modern farming methods than by mere formal schooling. For the effect of the agricultural work experience variable, it is negative (-0.008) and significant at 5% on the technical inefficiency. Indeed, for **Ogundari and Akinbogun (2010),** experience based on the acquisition of the best agricultural techniques over time through practice, negatively affects technical inefficiency. However, the paper of **Adinku et al., (2013)** revealed that many years of rice production only indicate adherence to old production methods that may be technically less efficient.

Household size has a negative effect (-0.016) and significant at 5% on the technical inefficiency. This finding supports the hypothesis that a large family size means more labor to meet the needs of agricultural activities **(Dhungana *et al*., 2004; Kaboré, 2007).** The number of fields defining the fragmentation of a farm, negatively (-0.013) and significantly affects the technical inefficiency. This relationship is explained by the fact that a geographical dispersion of fields can make it possible to diversify the risk. Indeed, in **Fontan (2008),** a producer holding distinct fields, better results may be observed on a particular field located on different reliefs.

Rice farmers whose main activity is agriculture would be technically more efficient because they would have more experience. Therefore, they would have more potential on the efficient use of agricultural inputs (**Adinku *et al*., 2013**). This result is not the case in this study. The effect of the main activity variable was positive (0.194) and significant at 1% on the technical inefficiency. Togolese rice farmers with agriculture as main activity, whose would diversify their energies on a diverse set of agricultural speculations, may be technically less efficient because of a suboptimal use of their available resources. The results also show that rice farmers operating on their own land are less efficient than those operating on leased land. The effect of this variable is negative (-0.626) and significant at 1%. This finding is consistent with the hypothesis that long years of leasing would motivate farmers to work harder to meet their contractual obligations (**Helfand and Levine, 2004; Coelli *et al*., 2005**). Also, a negative relationship would be linked to the constraints of the agency, reflecting the problems of surveillance and therefore, a decrease in the performance of companies (**Giannakas *et al*., 2003; Reddy, 2002).**

Technical Efficiency Estimates

The technical efficiency scores of Togolese rice farmers are between 37.14% and 99.51% and are on average 79.72% (Fig. 3). This means that without using additional resources, rice farmers can increase their production by 20.28% on average. They can also reduce their production costs by 20.28% to be technically efficient. The mean equality tests show that there exists a significant difference between the mean technical efficiencies of the different regions of Togo.

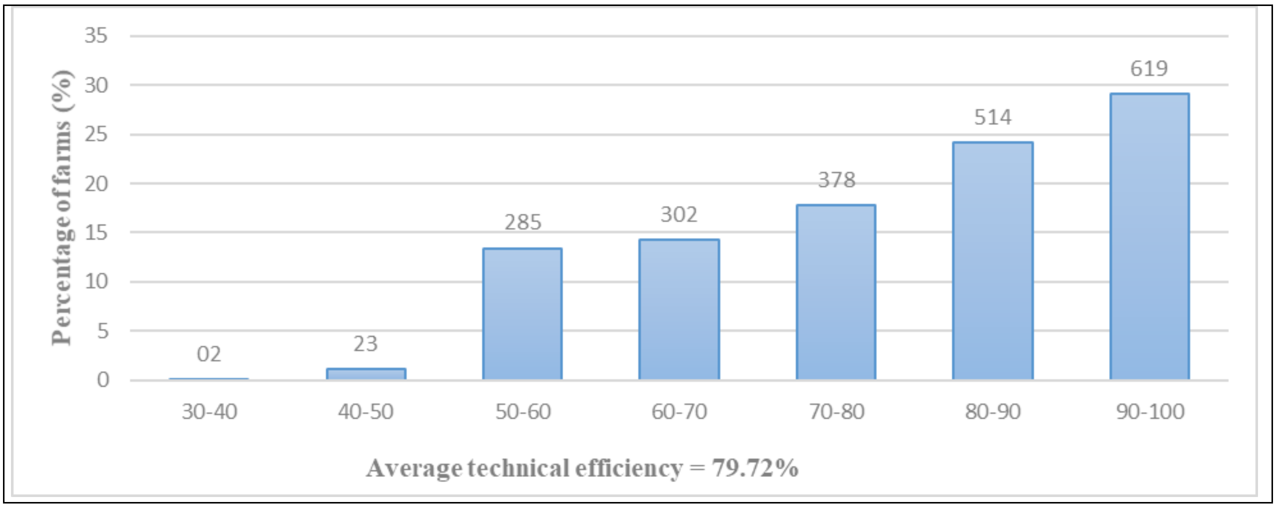

Figure 3 Graphical representation of technical efficiency scores
Source: Authors design based on the Fourth National Census of Agriculture data, Togo.

CONCLUSIONS AND RECOMMENDATIONS

The present study reveals through its results that production risk and technical inefficiency prevent Togolese rice farmers from realizing their frontier output. The production risk is significantly explained by production variables such as the land, the quantities of seeds and fertilizers used and the labor. The technical inefficiency is significantly explained by a set of exogenous variables such as gender, age, educational level, Experience, household size, number of fields and the main occupation of the rice farmer. The results also reveal a significant difference in mean technical efficiencies of the different Regions. In light of the findings, it is recommended that the Togolese government: (i) raise the price of rice to make rice production more attractive, (ii) further subsidize input prices to ensure that they are easily accessible and affordable to producers, and (iii) organize training sessions on the best use of modern capital. Thus, the results of this analysis are of particular interest to the Togolese economy in general and to the rice sector in particular, which is facing very strong demand. However, panel data would provide better estimates of observed phenomena than cross-sectional data (**Kumbhakar, 1993; Wan and Battese, 1992**). In perspective, incorporating the risk preference function into the flexible production risk model would allow for the study of producers' behaviors towards input allocation decisions **(Kumbhakar and Tveteras, 2003).**

Acknowledgement

This research paper was conducted by M. A. in framework of a doctoral programme under the supervision of Prof. A. E. A. Sincere gratitudes go to Ministry of Agriculture of Togo for the database. The authors would like to thank the anonymous referees for constructive comments that improved the contents and presentation of this paper.

REFERENCES

ABDULAI, J., NELSON, G. C., THOMAS, T. S., ZOUGMORE, R. & ROY-MACAULEY, H. (2013). West African agriculture and climate change: a comprehensive analysis. IFPRI Research Monographs, Washington DC, USA, 408 p. DOI: http://dx.doi.org/10.2499/9780896292048

ADINKU, E. O., ONUMAH, E. E. & MENSAH-BONSU, A. (2013). Production Risk and Technical Efficiency of irrigated rice farms in the Greater Accra and Volta Regions of Ghana. University of Ghana. http://ugspace.ug.edu.gh.

AIGNER, D. J., LOVELL, A. K. & SCHMIDT, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics, 6,* 21-37. DOI: https://doi.org/10.1016/0304-4076(77)90052-5

AJIBEFUN, I. A. (2008). An Evaluation of Parametric and Non-Parametric Methods of Technical Efficiency Measurement: Application to small scale food crop production in Nigeria. *Journal of Agriculture & Social Sciences*, ISSN Print: 1813–2235. http://www.fspublishers.org

ALI, E. (2019). Farmers' attitudes towards climate risks and effects of farmers' risk aversion behavior on inputs use in northern Togo. *Sarhad Journal of Agriculture*, *35*(3), 663-674. DOI: http://dx.doi.org/10.17582/journal.sja/2019/35.3.663.674

ASCHE, F. & TVETERAS, R. (1999). Modeling Production Risk with a Two-Step Procedure. *Journal of Agricultural and Resource Economics*, *24*(2), 424-439. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.494.3187&rep=rep1&type=pdf

BATTESE, G. E. & COELLI, T. J. (1988). Prediction of firm level technical efficiency with a generalized frontier production functions and panel data. *Journal of Econometrics, 38*(1988) 387-399. DOI: https://doi.org/10.1016/0304-4076(88)90053-X

BATTESE, G. E. & COELLI, T. J. (1995). A model for Technical Efficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics*, *20*, 325-332. DOI: https://link.springer.com/article/10.1007/BF01205442

BATTESE, G. E., RAMBALDI, A. N. & WAN, G. H. (1997). A Stochastic Frontier Production Function with Flexible Risk Properties. *Journal of Productivity Analysis, 8*(3), 269-280. https://doi.org/10.1023/A:1007755604744

BATTESE, G. E. & CORRA, G. S. (1977). Estimation of a Production Frontier Model: With application to the Pastoral Zone of Eastern Australia, *Australian Journal of Agricultural Economics*, *21*, 169-179. DOI: 10.22004/ag.econ.22266

BOKUSHEVA, R. & HOCKMANN, H. (2006). Production Risk and Technical Inefficiency in Russian Agriculture. *European Review of Agricultural Economics*, *33*(1), 93-118. DOI: 10.1093/erae/jbi036.

CHARNES, A., COOPER, W. W. & RHODES, E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research*, *2*(4), 429-444. DOI: https://doi.org/10.1016/0377-2217(78)90138-8

COELLI, T. J. & BATTESE, G. E. (1996). Identification of factors which influence the technical inefficiency of Indian farmers. Australian. *Journal of Agricultural Economics*, *40*, 103-128. DOI: 10.22004/ag.econ.22395

COELLI, T. J., Rao, D. S. P., O‟DONNELL, C. J. & BATTESE, G. E. (2005). An Introduction to Efficiency and Productivity Analysis, 2nd Edition, Springer Publishers, U.S.A. https://doi.org/10.1007/b136381

DHUNGANA, B. R., NUTHALL, P. L. & NERTEA, G. V. (2004). Measuring the economic inefficiency of Nepalese Rice Farmers using data envelopment analysis. *Australian Journal of Agricultural and Resource Economics*, *48*(2), 347-369.

Institut Togolais de Recherche Agronomique, Direction des Statistiques agricoles, de l'Informatique et de la Documentation et le Centre du riz pour l'Afrique (2014). Renforcement de la disponibilité et de l'accès aux statistiques rizicoles: une contribution à l'initiative d'urgence pour le riz en Afrique subsaharienne, rapport Togo.

FAO (2011). Stratégie de gestion des risques de catastrophe en Afrique de l'Ouest et au Sahel 2011-2013. https://duddal.org/s/bibnum-promap/item/4448

FARRELL, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society, 120*(3), 253-290. DOI: https://doi.org/10.2307/2343100

FONTAN, C. (2008). Production et efficience technique des riziculteurs de Guinée: Une estimation paramétrique stochastique. *Economie Rural*, 6(308), 19-35. DOI : http://journals.openedition.org/economierurale/342

GEMENNE, F., BLOCHER, J., DE LONGUEVILLE, F., VIGIL DIAZ TELENTI, S., ZICKGRAF, C., GHARBAOUI, D. & OZER, P. (2017). Changement climatique, catastrophes naturelles et déplacements de populations en Afrique de l'Ouest. Geo-Eco-Trop_Final, 22p.

GIANNAKAS, K., TRAN, K. C. & ZOUVELEKAS, T. V. (2003). Predicting Technical Efficiency in Stochastic Production Frontier Model in the Presence of Misspecification: A Monte- Carlo Analysis. *Applied Economics, 35*(2), 153-161.

GUTTORMSEN, A. G. et ROLL, K.H. (2013). Production Risk in a Subsistence Agriculture, *The Journal of Agricultural Education and Extension*, DOI: http://dx.doi.org/10.1080/1389224X.2013.775953

HELFAND, S. & LEVINE, E. S. (2004). Farm Size and Determinants of Productive Efficiency in Brazilian Centre-West. *Agricultural Economics, 31*, 241-249.

JUST, R. E. & POPE, R. D. (1978). Stochastic Representation of Production Functions and Econometric Implications. *Journal of Econometrics*, 7.

KABORÉ, D.P. (2007). Efficience technique de la production rizicole sur les périmètres aménagés du Burkina Faso. Série document de travail, DT-CAPES N°2007-35.

KARA, A. H., SHAMSUDIN, M. N., MUHAMED, Z., LATIF, I. A., SENG, K. WK., & ABOKI, E. (2019). Modeling Technical Efficiency with Production Risk: A breakdown of Kebbi State rice farms. *Advances in Environmental Biology, 13*(7), 17-24. DOI:10.22587/aeb.2019.13.7.3

KHREISAT, M. A. (2011). Production Function Estimation and Policy Implications. Fort Collins, Colorado: Department of Economics.

KIBAARA, B. W. (2005). Technical Efficiency in Kenyan's Maize Production: An application of the stochastic frontier approach. Department of Agricultural and Resource Economics, MSc. Thesis, Colorado State University.

KODDE, D. A. & Palm, A. C. (1986). Wald Criteria for jointly testing equality and inequality restrictions. *Econometrica*, *54*, 1243-1248.

KUMBHAKAR, S. C. (1993). Production risk, technical efficiency, and panel data; Department of Economics, University of Texas at Austin, TX 78712.1173. USA.

KUMBHAKAR, S. C. (2002). Specification and estimation of production risk, risk preferences and technical efficiency. *American Journal of Agricultural Economics, 84*, 8-22.

KUMBHAKAR, S. C. & TVETERAS, R. (2003). Risk Preferences, Production Risk and Firm Heterogeneity. *Scand. J. of Economics, 105*(2), 275–293.

KUMBHAKAR, S. C. & TSIONAS, E.G. (2010). "Estimation of production risk and risk preference function: a nonparametric approach." *Annals of Operations Research* (2010) 176: 369–378. DOI: 10.1007/s10479-008-0472-5

LOVE, H. A. & BUCCOLA, S. T. (1991). Joint Risk Preference-Technology Estimation with a Primal System. *American Journal of Agricultural Economics ,73*, 765-774.

MAMILIANTI, W., HANANI, N., MUSLICH MUSTADJAB, M. & ASMARA, R. (2019). Risk preference of farmers and production input allocation of potato farming in Tengger highland, Indonesia. *Eurasia J Biosci, 13*, 1777-1783.

MEEUSEN, W. & VAN DEN BROECK, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed errors. *International Economic Review, 18,* 435-444. DOI: https://www.jstor.org/stable/2525757

Ministère de l'Agriculture, de l'Elevage et de la Pêche (2010). Stratégie Nationale de Développement de la Riziculture (SNDR) au Togo.

Ministère de l'Agriculture, de l'Elevage et de la Pêche et la Direction des Statistiques Agricoles, de l'Informatique et de la Documentation (2013). 4ème Recensement National de l'Agriculture 2011 - 2014, Volume I.

Ministère de l'Agriculture, de l'Elevage et de la Pêche et la Direction des Statistiques Agricoles, de l'Informatique et de la Documentation (2014). Les principales caractéristiques de l'agriculture togolaise. 4ème Recensement National de l'Agriculture 2011 - 2014, Volume VI.

NGOM, C. A. B., SARR, F., & FALL, A. A. (2016). Mesure de l'efficacité technique des riziculteurs du bassin du fleuve Sénégal. *Economie Rurale*, *5*(355), 91-105. DOI: https://doi.org/10.4000/economierurale.5021

NUAMA, E. (2006). Mesure de l'efficacité technique des agricultrices de cultures vivrières en Côte-d'Ivoire. *Economie Rurale*, *296*, 39-53.

OGUNDARI, K. & AKINBOGUN, O. (2010). Modeling Technical Efficiency with Production Risk: A Study of Fish Farms in Nigeria. *Marine Resource Economics*, *25*, 295–308. https://doi.org/10.5950/0738-1360-25.3.295

ONUMAH, E. E., BRÜMMER, B. & HÖRSTGEN-SCHWARK, G. (2010). Elements Which Delimitate Technical Efficiency of Fish Farms in Ghana. *Journal of the world aquaculture society*, *41*, 506-5018. DOI: https://doi.org/10.1111/j.1749-7345.2010.00391.x

OPPONG, B. A., ONUMAH, E. E., & ASUMING-BREMPONG, S. (2016). Technical efficiency and production risk of maize production: evidence from Ghana. *Asian J. Agric. Extens. Econ. Soc.*, *11*(3), 1-9. DOI: https://doi.org/10.26796/jenrm.v3i2.90

OWUOR, G. & SHEM, O. A. (2009). What Are the Key Constraints in Technical Efficiency of Smallholder Farmers in Africa: Empirical Evidence from Kenya. A Paper Presented at 111 EAAE-IAAE Seminar „Small Farms: decline or persistence" University of Kent, 26-27th June. DOI: http://dx.doi.org/10.22004/ag.econ.52807

PICAZO-TADEO, A. J. & WALL, A. (2011). Production risk, risk aversion and the determination of risk attitudes among Spanish rice producers. *Agricultural Economics Journal*, 451-464. DOI: https://doi.org/10.1111/j.1574-0862.2011.00537.x

POPE, R. D. & KRAMER, R. A. (1979). Production Uncertainty and Factor Demands for the Competitive Firm. *Southern Economic Journal*, *46*, 489-501. DOI: https://doi.org/10.2307/1057421

REDDY, M. (2002). Implications of Tenancy Status on Productivity and Efficiency: Evidence from Fiji. *Sri Lankan Journal of Agricultural Economics*, *4*, 19-37. DOI: http://dx.doi.org/10.22004/ag.econ.205597

ROPPA (2016). « Ten Years After the Maputo Declaration on Agriculture and Food Security: An Assessment of Progress in West Africa: CASE OF TOGO. ». https://roppa-afrique.org/IMG/pdf/togo_rapport_final-kf.pdf

TIEDEMANN, T. et LATACZ-LOHMANN, U. (2013). « Production Risk and Technical Efficiency in Organic and Conventional Agriculture – The Case of Arable Farms in Germany ». *Journal of Agricultural Economics*, 64(1), 73–96. DOI: 10.1111/j.1477-9552.2012.00364.x

TRAN, D. T. (2019). Technical efficiency, technical change and return to scale of rice, maize and agricultural production in Vietnam. Georg-August-University Göttingen: Faculty of Agricultural Sciences, Germany.

VILLANO, R. A. et FLEMING, E. (2006). Technical inefficiency and production risk in rice farming: Evidence from the central Luzon Philippines. *Asian Economic Journal*, *20*(1), 29-46. DOI: https://doi.org/10.1111/j.1467-8381.2006.00223.x

VILLANO, R. A., O''DONNELL, C. J. & BATTESE, G. E. (2005). An Investigation of Production Risk, Risk Preferences and Technical Efficiency: Evidence from Rainfed Lowland Rice Farms in the Philippines. University of New England. http://dx.doi.org/10.22004/ag.econ.12953

WAN, G. H. & BATTESE, G. E. (1992). A stochastic Frontier Production function incorporating flexible risk properties. Paper presented at the Australasian Meeting of the Econometric Society, Monash University, Melbourne, July 1992.