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Socio-Economic, Pedological and Climate Determinants of Producers' Technical Efficiency in Mali

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Abstract

This paper uses data from the National Surveys' data from the Living Standards Measurement Study and the Integrated Surveys on Agriculture for Mali of 2014 to analyze socio-economic, pedological and climate determinants of producers' technical efficiency in Mali. To do so, a stochastic production frontier was estimated for each crop category and the full sample. Globally, the finding is that different stochastic parameters affect significantly the technical efficiency of different crop categories producing plots. On average, we have an efficiency score of 55.00% for the full sample. The cash crop producing plots are technically more efficient than cereal crop producing plots. Regarding the results, the setting up the following measures is highly recommended: provide adequate training methods of new technologies and new agricultural practices for cereal crop producers, crop diversification must be introduced to the production system and the promotion of better irrigation systems.

Keywords: socio-economic, pedological, climate, technical efficiency Mali and categories
JEL classifications: **C**21, **Q**16, **Q**18, **Q**51, **Q**54

1. Introduction

The main cause of food availability of smallholder farmers in developing regions and countries is the production efficiency level. African sub-Saharan countries are the most touched by this phenomenon. In Mali where the most produced and consumed cereals are rice, millet, sorghum, cotton and maize. The respective yields of these cereals are lower than their potential yields (CSA[5], 2011). In the period 2001-2010, significant fluctuation of their yields was noted with a significant increasing of cultivated area of the main crops in the period 2009-2015 was also noted (EAC / CPS / SDR, 2014/2015). In Mali, agriculture is practiced under random climatic conditions with significant risks of drought or of flood. It therefore undergoes significant fluctuations related to the poor distribution of rains over time. This is why in the last 20 years, without a very pronounced drought, agricultural production has varied from one to two between the worst and the best. This inter-annual and inter-season variability is one of the main factors of vulnerability of producers (CILSS, 2002). Malian's economy is, by its current characteristics, very exposed to climatic risks. In 2010, the agricultural sector accounted for over 80% of the labor force and accounted for 38.5% of Gross Domestic Product (GDP), while the industrial sector accounted for only 16.9% of GDP and the tertiary sector (trade, services) 37.6% (CSCRP[6], 2010).

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The share of the agricultural sector is declining as it accounted for only 30% of GDP in 2012 (INSTAT[7], 2013). According to the World Bank in 2014, more than 55.6% of the population lived below the national poverty line and the food insecurity rate was 25% in February 2015 according to ENSAN[8].

Most of producers in the country are weakly endowed, do not have much agricultural knowledge and have many social and financial constraints. That leads to a low technical efficiency score of producers. Facing all these observations, the Malian authorities have developed some plans to help producers through the adoption of the national policies and strategies. In additional to that, we have the intervention of some local and international NGOs in the agricultural sector through support to small producers. Despite all these efforts, the problem of productivity fluctuation persists and becomes more and more worrying. Producers therefore should adopt some strategies to increase their technical efficiency, such as the choice of crops, the acquisition of modern equipment, the adoption of modern farming practices, and so on. These allow reducing the problem of productivity fluctuation. Determining the socioeconomic, pedological and climatic determinants of the technical efficiency of crop categories producers in Mali will allow them to stabilize the production's level. This work is therefore a scientific tool of crop choice for producers to increase their technical efficiency score on average for ensuring food security in the country.

The overall objective of this paper is to determine, compare and analyze the technical efficiency scores of producers of different crop categories in Mali. Firstly, crop categories producers' technical efficiency scores will be estimated on average; secondly, a comparison between different crop categories producers' technical efficiency scores on average will be made; finally, a comparative analysis of the different crop categories producers' technical efficiency determinants will be implemented. The rest of the document breaks down as follows: the second part presents the notion of agricultural production linked to the technical efficiency, agricultural technical efficiency in Mali and agricultural production systems in Mali; The Method and tools are exposed in the third part; the fourth part is devoted to the results and discussions; finally, the last part presents the conclusion.

2. Background and context

This section presents the notion of agricultural production linked to the technical efficiency, agricultural technical efficiency and agricultural production Systems in Mali

2.1. Agricultural production and technical efficiency

Two approaches are usually used for the technical efficiency analysis: non-parametric and parametric approaches. The last one is known as the Stochastic Frontier Analysis (SFA) and uses econometric methods and statistical tests to estimate a production function. This approach allows separating the impact share of random phenomena from the inefficiency due to production system (Chemak and Dhehibi, 2010). The nonparametric approach (Data Envelopment Analysis, determinist) considers that all the deviation of the production frontier is due to the producer's inefficiency. In additional to that, the use of stochastic frontier method in determining production efficiencies or inefficiencies is encouraged by the modeling ease of farm production variables because of its ability to represent time or production cycles, and that the production function. The exogenous effects influencing technical efficiency are estimated simultaneously (Agbonlahor et al., 2007). For its advantages, Stochastic Frontier production approach is used in this study to analyze cereal and cash crops production efficiency and their determinants. It was introduced by Aigner, Lovell and Schmidt (1977) and Meesen and Van de Broeck (1977). This approach is used by several scholars in research field and scientists, particularly in agricultural production. Thus, several authors used stochastic frontier production to estimate farm production efficiency and its determinants.

Abdulai (2006), estimated a stochastic frontier for a sample of 135 vegetable producers in Kumasi, found that inefficiency in the vegetable production system exists and the mean technical efficiency score is 66.67% for the pooled sample. Efficiency score varies across all production units ranging from 12.9% to 95.02%. Chandio et al, (2017) using SFA investigated the Nexus of Agricultural Credit, Farm Size and Technical Efficiency in Sindh, Pakistan. Findings revealed that 97% of rice farmers are technically efficient and credit, farm size, fertilizer, and labor significantly influenced the rice productivity.

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[7] Institut National de Statistiques (National Institute of Statistics)

[8] Enquête National sur la Sécurité Alimentaire et Nutritionelle (National Survey on Food and Nutrition Security)

Bozoglu and Ceyhan (2007) found that the average output of vegetable farmers in Samsun (Turkey) could increase by 18% under prevailing technology where technical efficiency ranged from 56 to 95%. Access to education, experience, credit use, participation by women and information score negatively affected technical inefficiency. However, age, family size, off-farm income share and farm size showed a positive relationship with inefficiency. The empirical results of rice production in Cambodia and Thailand showed a relative high technical efficiency of the small-scale farmers but relatively poor scores on systematic input price efficiency. The access to extension services as well as agricultural training on the farm level is found to have a positive effect on the technical efficiency level of the farms. All model specifications further agree on the negative effect on efficiency with respect to the use of insecticides (Ebers et al, 2017).

Hasnain (2015) found that farmers can increase their production by 10.5% through the increasing of labor, seed and irrigation inputs and also by using adequate quantity of fertilizer and pesticide inputs. Indeed, farm size and ploughing cost are found to have an insignificant effect on the technical efficiency of Boro (Bangladesh) rice production in the study area. Technical efficiency of Swaziland maize producers could also be increased by 10% through better use of available resources. It was found to be positively associated with farmers' age, having off-farm income, farmers' experience, intercropping and use of hybrid seeds (Dlamini et al, 2012).

Studies were devoted on technical efficiency analysis in Africa. Amos et al, (2004) investigated productivity, technical efficiency and cropping patterns in the savanna zone of Nigeria. The main findings showed that the technical efficiency of the sole maize farmers on average was lower (0.53) compared to that of the mixed (yam/maize) cropping farmers (0.72). The efficiency score on average of 0.62 was observed for all farmers. Over 50% of the mixed crop farmers had technical efficiency scores that exceeding 0.70 as compared to 100% sole farmers who had less than 0.60. Study further showed that years of schooling, farming experience and cropping pattern positively affected technical efficiency while increase of age have a negative effect on the technical efficiency. Nuama (2006) found that both crops producers are technically efficient with a technical efficiency score of 0.88 on average for yam producers' across 0.80 for Cassava ones. The main crop producers in the area of study are less intensive in capital. This is due to the using of too many quantities of labor by producers on few area of land. The household size, access to extension services and credit increases the producers' efficiency score. Elsewhere, results from Nuama (2010), revealed that in the full sample, the main determinant of producers' efficiency are participation to a help group, access to credit, access to land and cash crop planting compared to access to extension service that is not a determinant of rice producers. Ohajianya et al, (2006) indicated that technical inefficiency in food crops production in Imo State, Nigeria ranges of 0.21 to 0.98 with a mean of 0.61. Those results suggest that there are still opportunities for increasing productivity and farm income in Imo State through reduction in technical inefficiency in resource use. Major factors inversely related to technical inefficiency are education, farm size, access to credit, extension contact, farming experience family and labor used, while household size and age were found to be directly related to technical inefficiency.

2.2. Agricultural technical efficiency in Mali

Scientific works were done on agricultural production efficiency in Mali. Audibert (1997) investigated the technical efficiency score of paddy farmers in the area of "Office du Niger", Mali. The technical efficiency score for paddy farmers on average are estimated to be between 0.68 and 0.71. About 15% of the farms have a technical efficiency score on average lower than 0.5 and less than 60% have a technical efficiency score higher than 0.7. The main causes of inefficiency are the environment and confirm the benefits of the retail or Arpon plot schemes. Indeed poor irrigation schemes and irregular level of plots have stronger effects than weak access to extension services. Coulibaly et al. (2017) by analyzing rice farmers' technical efficiency in Mali using Cobb Douglas functional form found that the rice cultivation at the Office Niger evolves a non-constant returns to scale framework. The technical efficiency score on average is 0.66, implying that the level of technical efficiency can be improved by 0.34 without additional cost. In additional to that, experience, equipment, being member of a farmer's organization and land rental are identified as statistically significant determinants of technical efficiency of rice farmers in the area of study. Policies to improve the level of technical efficiency and boost rice production in Mali should be based on these variables.

2.3. Agricultural production systems in Mali

The production systems, the characteristics of crops, production equipment, soil qualities, climate, agricultural labor, technologies and the production conditions are the most determinant of crop choice in Mali. Regarding the results of the 2007 RuralStruc survey, in the Macina area (in the "Office du Niger"), the gross agricultural product is almost exclusively based on rice (78%) and shallot (18%).

In Koutiala (the cotton production area), a not inconsiderable part of the gross product is constituted with maize (15%); cotton occupies a still important place (27%) even if the areas cultivated have decreased compared to previous years; the rest is millet (22%) and sorghum (24%) (Traoré et al., 2011).

Varietal selection of sorghum has resulted in productive varieties, but these are not well adapted to extensive farming systems, that lead to the poor adoption of these varieties by farmers in producers in Mali. The photosensitivity of local varieties is strong, even with photoperiodic differences of a few minutes. Depending on the sowing date, the duration of the cycle varies between 90 and 190 days, a sowing lag of 15 days can (late March, in the off-season) delay the duration of the cycle by several months. In contrast, this characteristic has been eliminated in previous selections, while it gives great flexibility of adaptation (Vaksmann et al., 1996).

Variety selection criteria are divided into four main groups: environmental adaptation, productivity, quality and maintenance of genetic diversity. The broadening of the genetic base to many local varieties has made it possible to show the contribution of the genes of the local varieties to nearly 70% in the base population. Photoperiodism gives the varieties obtained a great phenological plasticity, the material remains effective regardless of the date of sowing. Natural tillering of local varieties has been preserved, allowing yields to reach 4 t/ha even at low planting densities (Vaksmann et al., 2008).

3. Method and Tools

The theoretical, empirical Modeling and Data and variables descriptions are exposed in this section.

3.1 The model's Theoretical specification

Production in agriculture is to combine many production factors (e.g., land, seed, labor, and capital) to obtain an output. Agricultural production input may differ in terms of substitutability or quality. For example, a plot might be plowed using an animal traction or a tractor or planted with an improved seed varieties rather than traditional seed varieties for yield's increases. The most important issue of farmers is how to choose the best technology of inputs combination which can maximize the profit and minimize the cost of those inputs. The producer's productivity is commonly measured in terms of technical efficiency, i.e., the ratio of output that is produces from a combination of a given set of inputs. The estimation of production functions (or frontiers) which model gives the maximum level of output produced from a specific set of inputs given the technology available to a farmer to determine his technical efficiency level (Coelli et al., 2005).

The following model can helps to estimate the technical efficiency level achieved on plot i (or farm). Aigner et al. (1977) and Meeusen and van den Broeck (1977) are the most known authors that used the following log-linear Cobb- Douglas functional form to represent the production function: $\ln y_i = X_i \beta \ \exp(v_i - u_i) \ (1)$,

where y_i is log transformed output, X_i is a vector of inputs variables log transformed, β is a vector of parameters to be estimated, v_i is a symmetric random variable, and u_i is a nonnegative random variable. The two terms v_i and $u_i$comprise a dual error term in which v_i captures statistical noise (e.g., exogenous shocks beyond producers' control and measurement error) and u_i reflects technical inefficiency in the gap between the production frontier and producers' efficiency level. Following the model proposed by Caudill et al. (1995), u_i is assumed to be distributed half-normal $N + (\mu, \sigma_{ui}^2)$, with its variance a function of exogenous determinants of technical inefficiency, $\sigma_{ui} = \exp(Z_i \delta)$, where Z_i is a vector of exogenous determinants of technical inefficiency for i^{th} farm and δ is a vector of unknown parameters to be estimated. Based on this model, it is possible to predict ui and calculate technical efficiency as: $TE_i = \exp(-u_i) \ (2)$ (Jondrow et al., 1982). With Maximum likelihood estimation, it is possible to estimate both production frontier and technical inefficiency components.

3.2 The model's empirical specification

Cobb-Douglas or transcendental logarithmic (translog) function are the most known functional forms used to estimate the production function or frontier. This specification allows simplifying the functional form and facilitates the interpretation of the parameters. But the Cobb-Douglas functional form is less flexible than the translog one because it imposes some restriction like unitary elasticity of substitution (It supposed perfectly complementary between production factors) or with translog functional form, that can be avoided. In this study, the statistical test chows that the best functional form for this data is the translog specification (see Table2).

The following Cobb-Douglas and translog production functions for a single output, K = 4 inputs are implemented for both crop categories and the full sample:

$$\ln y_i = \alpha_i + \sum_{k=4}^{K} \beta_k \ln x_{ki} + v_i - u_i \quad (2)$$

and

$$\ln y_i = \alpha_i + \sum_{k=4}^{K} \beta_k \ln x_{ki} + 1/2 \sum_{k=4}^{K} \sum_{l=4}^{L} \beta_{kl} \ln x_{ki} \ln x_{li} + v_i - u_i \quad (3)$$

where y_i and x_{ki} represent the log transformed total value of output and the k^{th} production input (land, purchased seed, labor and other variable inputs) for the i^{th} plot, respectively; $v_i \sim N(0, \sigma_v^2), ui \sim N + (\mu, \sigma_{ui}^2)$, and $\sigma_{ui} = \exp(Z'_i \delta)$. Z_i is a vector of exogenous determinants of technical efficiency for the i^{th} plot that includes household structure, access to credit, and household migration rate. In addition, it contains several other relevant individual, household, and plot-size control variables, as well as regional fixed-effects. Those indicators are included to account for any unobservable characteristics not captured by the other indicators in the model (e.g., infrastructures, market access, and climate indicators). This will allow the estimation of the technical efficiency score of producers in southern Mali for each category of crops and find their endogenous and exogenous determinants (age, educational level, child ratio, gender, access to extension services, household size, remittance, access to credit, access to subsidies, access to technologies, income share from off farm activities, crop association practice, rainfall, temperature, soil characteristics, soil reliefs and regional variable). Thus a comparative analysis across crop categories will be implemented.

3.3 Data and variables

The analysis uses a national Surveys' data from the Living Standards Measurement Study and the Integrated Surveys on Agriculture (LSMS-ISA) for Mali of 2014 founded by the World Bank Group. The Survey were conducted by the Planning and Statistics Unit of the Ministry of Rural Development under the guidance of the Group World Bank team, this data set is a national representative one that covers all the regions in the country (excluding Kidal region). An advantage of this data set is that it is collected at the plot level allowing then to identify the plot manager's (decision maker). The plot manager decides what to be done on the plot regarding inputs uses, crop choices, equipment choices and the income management within the household.

The data was collected from five regions of Mali, including the capital city (Bamako). Regarding the objectives of the study, only agricultural households that cultivated plots during the rainy season in 2014 were considered in the analysis. Starting with 3,992 households in both waves in the LSMS-ISA, 1,336 households with 5,099 plots were analyzed in this study. The data set includes only plots over or equal to 100 m^2 with those where information on the plot manager's age and level of education. About 2,656 households were then dropped from the data set in which 1,748 were non-agricultural households (about 44%), the other 20% households that were dropped contain either no harvest information, unexploited plots, contain non-logical information, do not grow main crops (millet, sorghum, rice, maize, fonio, beans, groundnut, bambara-nut or sesame) or belong to non including regions.

However, some special cases were corrected with standard statistical approaches. On about 24% of the 5,099 plots, producers grow cash crops. This cleaned data covers Kayes, Koulikoro, Sikasso, Segou and Mopti regions. In Table 1, we have a full descriptions and the summary of all variables used on average by category of crop and in the full sample.

Table 1: Descriptive Statistics of the variables

Variables	Descriptions		Means or %			
			Cereals crops	Cash crops	Differences	Total
Value of crops harvested (output)	Value of crops harvested on the plot during last 12 months in FCFA		216,845.70	118,615.20	98230.50***	193,535.50
Area of plot	Area of plot per ha		0.88	0.60	0.28***	0.81
Purchased seed	Amount of seed purchased by plot manager in FCFA		1,404.57	1,798.67	-394.10**	1,498.09
labor used	Number of days worked by males, females and children on the plot		42.44	26.20	16.24***	38.58809
Other inputs value	Value of Herbicides, Fungicides and fertilizers used on the plot in FCFA		1,897.62	785.75	1111.87***	1,633.77
age	Age of the manager in completed year		42.20	38.98	3.22***	41.44
Education level	The manager has a primary school educational level		15.76	22.31	-6.55***	17.32
Child dependency ratio	Ratio of children (0–14 years old) in the manager's household		1.13	1.15	-0.02	1.14
Access to extension services (1 if yes)	The manager received a visit of extension services		22.71	22.15	0.56	22.57
Household size	The total number of household members		13.68	14.09	-0.41	13.78
Remittance (*100000 FCFA)	Quantity of money sent by household members living outside the household during a year in FCFA		1 6.34	33.88	-17.55	20.50
Access to credit (1 if yes)	The manager has access to credit		1.31	2.48	-1.17***	1.59
Access to subsidies (1 if yes)	The manager has access to subsidies		30.60	33.64	-3.04**	31.32
Access to technologies (1 if yes)	The manager has access to production technologies		74.62	75.04	-0.42	74.72
Income share from off farm activities	Off farm income share of the plot manager		0.04	0.03	0.01	0.03
Cropping System (1 if yes)	The plot manager practice crop association		7.25	5.70	1.55*	6.88
Rainfall	Quantity of rainfall on average during the rainy season in mm³		143.79	144.28	-0.49	143.90
Temperature	The level of the temperature on average during the rainy season in °C		34.64	34.51	0.13**	34.61
Soil loam (1 if yes)	The soil is loam		49.86	51.74	-1.88	50.30
Soil clay (1 if yes)	The soil is clay		38.54	34.05	4.49***	37.48
Soil red (1 if yes)	The soil is red		4.91	7.52	-2.61***	5.53
Soil other (1 if yes)	The soil is other type		6.69	6.69	0.00	6.69
Flat stop (1 if yes)	The soil is in flat stop position		65.88	66.86	-0.98	66.11
Slight steep (1 if yes)	The soil is in slight steep position		13.09	13.31	-0.22	13.14
Very steep (1 if yes)	The soil is in very steep position		0.62	0.83	0.21	0.67
other relief (1 if yes)	The soil is in other relief position		20.42	19.01	01.41	20.08
Gender	The gender of the plot manager	Male	54.87	45.87	9.00	52.74
		Female	45.13	54.13	-10.00	47.26
Observations			**3,889.00**	**1,210.00**	**5099**	**5099**

Source: Author's calculations based on 2014 LSMS-ISA data for Mali.

Notes: *, **, and *** correspond to significances of 10%, 5%, and 1% respectively.

The harvest value in this study is the proxy of the productivity[9] (in FCFA[10]). It is calculated by summing up the values of all crops harvested on the plot in CFA. On average, value of harvest for the full sample is 193,535.50 FCFA. On average, cash crops producing plot have less agricultural income than cereal crops producing plots in the area of study with a difference of 98230.50 FCFA (significant at 1%). Cash crops producing plots are less big than cereal producing plots, use less labor than them, have more other inputs value than them and have younger manager compared to them. That can explain the difference in harvest value across crop categories. But cash crops producing plots have more purchased seed than cereal producing plots. More cash crops producing plots managers attained a certain educational level than cereal producing plots. Their managers have more access to credit, subsidies and red soils. But they practice less crop association, produce under smaller temperature and have access to more clay soils than cereal producing plots.

4. Results and discussions

Here, a translog model is estimated for each crop category in the study to estimate their efficiency scores and analyzes its relationship with socio-economic, pedological and climate determinants. That allows a comparative analysis between crop categories. Table 2 shows the statistical tests that allow finding the best functional form for the data's structure. In Table 3, we have the estimated coefficients of production function for both crop categories produced on plots models. The last table shows the estimated coefficients of technical inefficiency factors for both crop categories produced on plots.

Table 2: statistical test for the functional form specification

Null hypothesis		Test Stat.	Result
Categories	**Specifications**		
Cash crops	Cobb-Douglas	38.212***	H_0 is Rejected
Cereal crop	Cobb-Douglas	123.704***	H_0 is Rejected
Full sample	Cobb-Douglas	123.764***	H_0 is Rejected

Source: Author's calculations based on 2014 LSMS-ISA data for Mali.

Notes: *, **, and *** correspond to significances of 10%, 5%, and 1% respectively.

The null hypothesis of Cobb-Douglas production function for each crop categories produced plots and the full sample is rejected at the 1% significance level. That conducts to the estimation of a translog functional form for all the models.

Table 3: Production frontier results for both categories of crop and the full sample

Variables.	ln output value Cash crop		ln output value Cereal crop		Full sample	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Cons.	-6.016***	1.464	3.564***	1.407	-0.432***	0.132
ln X_1	0.254***	0.052	0.233***	0.026	0.341***	0.059
ln X_2	0.155***	0.055	0.295***	0.032	0.135*	0.078
ln X_3	0.156***	0.044	0.147***	0.025	-0.087*	0.049
ln X_4	0.520***	0.139	0.316***	0.078	0.243**	0.112
½*ln X_1^2	0.031	0.083	0.001	0.036	0.044	0.033
½*ln X_2^2	0.082***	0.016	0.086	0.013	0.058***	0.011
½*ln X_3^2	-0.083*	0.045	-0.038*	0.022	-0.077***	0.020
½*ln X_4^2	-0.139	0.093	0.037	0.049	0.103**	0.044
½*ln X_1* ln X_2	-0.070	0.106	0.020	0.044	-0.009	0.038
½*ln X_1* ln X_3	0.101	0.077	-0.106***	0.035	-0.080***	0.031
½*ln X_1* ln X_4	0.326**	0.157	-0.141*	0.074	-0.098	0.099
½*ln X_2* ln X_3	-0.075	0.083	0.099**	0.042	0.128***	0.034
½*ln X_2* ln X_4	-0.086	0.153	-0.075	0.093	0.113	0.139
½*ln X_3* ln X_4	0.054	0.115	0.256	0.062	0.344***	0.080
Return to scale	1.084		0.990		0.63	
Efficiency score	0.997		0.485		0.55	
Observations	**1210**		**3889**		**5099**	

Source: Author's calculations based on 2014 LSMS-ISA data for Mali.

Notes: *, **, and *** correspond to significances of 10%, 5%, and 1% respectively.

Subscripts 1, 2, 3 and 4, refer to plot area, purchased seed, labor used and other inputs value, respectively

[9]The product value is calculated by the unitary value of the product sold before the survey.

[10]$ 1 US = 542.07 FCFA in 31/12/2014.

For all crop categories, we have an efficiency score of 55.00% and decreasing return to scale for a full sample which is not fare from other empirical studies of agricultural production in Mali and Africa (Coulibaly et al., 2017; Audibert, 1997; Ohajianya et al., 2006; Nuama, 2010; Nuama, 2016 and Amos et al., 2004). All the input variables have a positive effect on the productivity apart from labor used. Increasing the area of plot with the labor used quantity at the same time will have a negative and significant effect on the productivity. Increasing the purchased seed with labor used at the same time will have a positive and significant effect on the productivity. And increasing the labor used with other inputs value at the same time will have a positive and significant effect on the productivity. Child dependency ratio, household size, income share from off farm activities, crop association practice and rainfall quantity have a positive and significant effect on producers technical efficiency but Growing cash crops and increasing in temperature have a negative and significant effect. A deepening analysis of these results show a big difference in efficiency score on average between crop categories produced plots (99.7% for cash crop plots against 48.5% for cereal crop plots). An increasing return to scale for cash crop plots against decreasing return to scale for cereal crops plots with a significance rate of 1% for all input variables is also noted.

All the input variables have a positive effect on the productivity of both crop categories producing plots. The purchased seed at a certain quantity will significantly (1% significance level) have a positive effect on the production of cash crop plots but the quantity labor will significantly (1% significance level) have a negative effect on the production for both crop categories plot. Increasing the area of plot and the quantity of labor at the same time will have a negative effect (1% significance level) on the production for cereal producing plots. The increasing the area of plot and other production input will have a positive effect on cash crop producing plots (5% significance level) but a negative (10% significance level) on cereal crop producing plots. Access to subsidies, quantity of rainfall, quantity of temperature, producing on soil clay, producing on slight steep, producing on very steep and living in Sikasso region have a positive effect on cash crop producing plots' technical efficiency (based on 1 to 5% significance level). Access to credit and crop association practice have a negative effect on cash crop producing plots' technical efficiency. Having a certain educational level, child dependency ratio, remittance and temperature have a positive effect on cereal crop producing plots' technical efficiency (based on 1 to 10% significance level). The household size, access to technologies, Income share from off farm activities, crop association practice and quantity of rainfall a negative effect on cereal crop producing plots' technical efficiency (based on 1 to 5% significance level). The effects of access to credit can be explained by the low level of access to credit for both crop type producing plots. Elsewhere, producers maybe got credit for reimbursing other credit bank but also facing to other things different from farming activities.

Table 4: Technical inefficiency results for both categories of crop and the full sample

	ln output value Cash crop		**ln output value Cereal crop**		**Full Sample**	
Variables.	**Coef**	**S.E.**	**Coef**	**S.E.**	**Coef**	**S.E.**
Cons.	6.016***	1.464	3.564***	1.407	3.692***	0.930
age	0.001	0.003	0.003	0.002	0.002	0.002
Educational level (1 if yes)	-0.074	0.107	-0.253**	0.103	-0.109	0.069
Child dependency ratio	-0.079	0.061	-0.110**	0.055	0.099**	0.041
Access to extension services (1 if yes)	0.164	0.111	0.068	0.085	0.050	0.065
Household size	0.003	0.005	0.012***	0.004	0.006**	0.003
Remittance	0.000	0.000	-0.001*	0.000	4.801	5.467
Access to credit (1 if yes)	0.583**	0.276	-0.089	0.281	0.082	0.203
Access to subsidies (1 if yes)	-0.235**	0.103	0.025	0.085	0.009	0.064
Access to technologies (1 if yes)	-0.033	0.067	0.099**	0.050	0.046	0.039
Income share from off farm activities	-0.030	0.352	0.458**	0.210	0.236*	0.138
Crop association practice (1 if yes)	0.398**	0.193	0.366***	0.135	0.218**	0.102
Growing cash crops (1 if yes)	-	-	-	-	-0.124**	0.063
Rainfall	-0.009***	0.002	0.008***	0.002	0.005***	0.001
Temperature	-0.112***	0.039	-0.167***	0.037	-0.138***	0.024
Soil clay (1 if yes)	-0.286***	0.100	0.006	0.074	-0.001	0.056
Soil red (1 if yes)	0.111	0.171	0.088	0.153	0.081	0.112
Soil other (1 if yes)	-0.084	0.183	-0.042	0.155	-0.079	0.110
Slight steep (1 if yes)	-0.303**	0.133	-0.031	0.107	-0.046	0.080
Very steep (1 if yes)	-0.964**	0.461	0.223	0.504	-0.056	0.357
Other relief (1 if yes)	0.157	0.122	-0.054	0.091	0.020	0.070
Gender	-0.056	0.087	0.081	0.070	0.082	0.052
Region	-0.130**	0.056	0.310***	0.046	0.224***	0.032
Observations	**1210**		**3889**		**5099**	

Source: Author's calculations based on 2014 LSMS-ISA data for Mali.

Notes: *, **, and *** correspond to significances of 10%, 5%, and 1% respectively.

5. Conclusion

The global objective of this study is to determine, compare and analyze the technical efficiency scores of producers of cash and cereal crop categories in Mali. Specially it consisted to : determine crop categories producers' technical efficiency scores on average; Compare both crop categories producers' technical efficiency scores on average; and comparatively analyze of both crop categories producers' technical efficiency determinants. That by using data from the National Surveys' data from the Living Standards Measurement Study and the Integrated Surveys on Agriculture (LSMS-ISA) for Mali of 2014 funded by the World Bank Group.

Globally, the finding is that different stochastic parameters (socio-economic, pedologic and climate) affect significantly the technical efficiency of different crop categories producing plots and there is big difference (99.7% for cash crop plots against 48.5% for cereal crop plots) between crop categories producing plots in term of efficiency score on average. The cash crop producing plots are technically more efficient than cereal crop ones. This is mainly due to the fact that the cereal crop producing plots practice extensive production method and those of cash crop practice intensive production one. This is not fare from empirical studies in the same field in Mali and Africa (Coulibaly et al., 2017; Audibert, 1997; Ohajianya et al., 2006; Nuama, 2006; Nuama, 2010 and Amos et al., 2004). Crop categories have different factors that determine their technical efficiency as stated in the hypothesis. The effects of access to credit can be explained by the low level of access to credit for both crop type producing plots.

Regarding the results, the setting up the following measures is highly recommended to close the gap between producers' efficiency score on average: provide adequate training methods on new technologies and new agricultural practices for cereal crop producers, crop diversification must be introduced to the production system and the promotion of better irrigation systems. Above measures will increase the cereal producers' global technical efficiency score and reduce the efficiency gap across crop categories. This study can give more interesting results if the dynamic of the efficiency score of crop categories are analyzed with a panel specification of the production frontiers.

References

Agbonlahor, M. U., Momoh, S., & Dipeolu, A. O. (2007). Urban vegetable crop production and production efficiency. International journal of vegetable science, 13(2), 63-72.

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. Journal of Econometrics, 6 (1), 21-37.

Amos T. T., Chikwendu D. O. & Nmadu J. N. (2004). Productivity, technical efficiency and cropping patterns in the savanna zone of Nigeria. Food, Agriculture & Environment Vol.2 (2) : 173-176

Audibert, M. (1997). Technical inefficiency effects among paddy farmers in the villages of the 'Office du Niger', Mali, West Africa. Journal of Productivity Analysis, 8(4), 379-394.

Bozoğlu, M., & Ceyhan, V. (2007). Measuring the technical efficiency and exploring the inefficiency determinants of vegetable farms in Samsun province, Turkey. Agricultural systems, 94(3), 649-656.

Caudill, S. B., Ford, J. M., & Gropper, D. M. (1995). Frontier estimation and firm-specific inefficiency measures in the presence of heteroscedasticity. Journal of Business & Economic Statistics, 13(1), 105-111.

Chandio, A. A., Magsi, H., Rehman, A., & Sahito, J. G. M. (2017). Types, sources and importance of agricultural credits in Pakistan. Journal of Applied Environmental and Biological Sciences, 7, 144-149.

Chemak, F., & Dhehibi, B. (2010). Efficacité technique des exploitations en irrigué: une approche paramétrique versus non paramétrique. New Medit, 2, 32-41.

Coelli, T.J., Rao, D.S.P., O'Donnell, C.J., Battese, G.E. (2005). An introduction to efficiency and productivity analysis. Springer, New York.

Coulibaly A., SavadogoK. & Diakité L. (2017). Les Déterminants De L'efficience Technique Des Riziculteurs De L'office Du Niger Au Mali. Journal of Agriculture and Environmental Sciences. 6(2): 17-29

Dlamini, S. I., Masuku, M. B., & Rugambisa, J. I. (2012). Technical efficiency of maize production in Swaziland: A stochastic frontier approach. African Journal of Agricultural Research, 7(42), 5628-5636.

Ebers, A., Nguyen, T. T., & Grote, U. (2017). Production efficiency of rice farms in Thailand and Cambodia: a comparative analysis of Ubon Ratchathani and Stung Treng provinces. Paddy and water environment, 15(1), 79-92.

Hasnain, M. N., Hossain, M. E., & Islam, M. K. (2015). Technical efficiency of Boro rice production in Meherpur district of Bangladesh: A stochastic frontier approach. American Journal of Agriculture and Forestry, 3 (2), 31-37.

Jondrow, J., Lovell, C. K., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. Journal of econometrics, 19(2-3), 233-238.

Meeusen, W., & van den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. International Economic Review, 18(2), 435-444.

Nuama, E. (2006). Mesure de l'efficacité technique des agricultrices de cultures vivrières en Côte-d'Ivoire. Économie rurale. Agricultures, alimentations, territoires, (296), 39-53.

Nuama, E. (2010). L'efficacité technique des riziculteurs ivoiriens: la vulgarisation en question. Économie rurale. Agricultures, alimentations, territoires, (316), 36-47.

Ohajianya, D. O., Obasi, P. C., & Orebiyi, J. S. (2006). Technical inefficiency and its determinants in food crops production in Imor State, Nigeria. Journal of Agriculture and Social Research (JASR), 6(2).

Traoré, A., Soumaré, M., Bélières, J. F., et Hilhorst, T. (2011) "Quelles évolutions des systèmes de production céréaliers au Mali?". Grain de sel.

Vaksmann, M., Kouressy, M., Chantereau, J., Bazile, D., Sagnard, F., Touré, A., et Danté, A. (2008) "Utilisation de la diversité génétique des sorghos locaux du Mali". Cahiers Agricultures, vol.17 n°2, pp.140-145.

Vaksmann, M., Traoré, S. B., et Niangado, O. (1996) "Le photopériodisme des sorghos africains". Agriculture et développement, vol. 9, pp.13-18.

Reports or thesis

Abdulai, A. (2006). Resource use efficiency in vegetable Production: the case of smallholder farmers in the Kumasi metropolis. Thesis for Master Economic, this thesis submitted in partial fulfillment of the requirements for the Award of Master of Science degree in agricultural economics, University Science and technology. 121pp.

MEF, Cellule Technique CSLP : Rapport Synthèse de Revue du CSCRP 2007-2011 portant sur 2010.

Ministère de l'agriculture. (2013) "Recueil des statistiques du secteur du développement rural". pp. 27 et 28.

Ministère du Développement Rural. (2015) "Annuaire statistique 2014 du développement rural". pages 14 & 24.

Rapport de synthèse – MALI "Enquête Nationale sur la Sécurité Alimentaire et Nutritionnelle (ENSAN MALI - Septembre 2015) "

Toe, A. M. (2002) "Étude pilote sur les limites maximales de résidus de pesticides admissibles dans les produits agricoles dans trois pays sélectionnés du CILSS (Burkina Faso, Mali, Sénégal). Consultation nationale pour le Burkina Faso. Rapport technique: mission de consultation". Projet GCP/RAF/335/NET/FAO/CILSS Gestion des pesticides au Sahel.