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Effect of Agricultural Credit Access on Rice Productivity: Evidence from the Irrigated Area of Anambe Basin, Senegal

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Abstract

Rice is an important staple food in many developing countries, especially in Senegal. However, rice production in Senegal only meet 20% of the domestic demand largely due to the poor performance of rice farmers and low productivity. Access to agricultural credit has strong impacts on the technical efficiency of farmers and would promote inputs and new technology adoption. But that is not clear enough in previous studies. This study investigates the impact of agricultural credit access on rice productivity and technical efficiency with 260 random sampled rice farmers from Anambe basin in Senegal. The Stochastic Frontier Analysis (SFA) was adopted to estimate the technical efficiency. The results indicate that the inputs of rice production, including labor, pesticide, herbicides and fertilizer, have significant impacts on rice productivity. Furthermore, the results present that the average efficiency is of 0.813 and the inefficiency estimation model reveals that the influences of agricultural credit access, gender, education, ethnicity, use of improved seed and land tenure system on technical inefficiency of rice production are significant. Particularly, for the access to agricultural credit, rice farmers without agricultural credit would get 3.8% higher production inefficiency. The farmers with access to credit yield 37.32% higher rice production than their counterparts. Therefore, our study provides strong empirical evidence to promote agricultural credit in rice production.

Keywords: agricultural credit, rice productivity, technical efficiency, stochastic frontier analysis, irrigated area, Senegal

1. Introduction

Agriculture plays an important role in the economy of most developing countries. According to Otsuka (2013), agriculture provides 70% of full-time employment, 40% export earnings and also generates 35% national income in Africa. In Senegal, agriculture is a privileged sector which employs half of the labor forces, yet contributes 14.8% of the GDP (Seck, 2019). This poor performance of agriculture sector in Senegal is partially caused by the lack of financial supports rendered to farmers and inadequate incentive programs dedicated to the productivity improvement.

Rice is a cash crop and an important staple food in Senegal. In 2015, the average consumption was reported to be 72.29 kg/person/year by FAO (2015). However, the Senegalese rice production only meets 20% of the domestic demand. This leads a large volume of rice imports which piles up from 650000 to 850000 tons and the bulk cost of 165 billion XOF on average (PNAR, 2014). To improve the rice production performance and achieve self-sufficiency, the Senegalese government carried out an economic policy in 2014 to boost annual paddy rice production to the level of 1600000 tons. The government focused on the cultivation of irrigated rice in the Senegal river valley and Anambe basin. That areas account for 5% of the total arable land in Senegal but yield 83% of the total rice production (PRACAS, 2014). Though the implementation of the policy came up with some positive results, such as increasing the national rice production from 436153 to 1007277 tons over the period of 2014-2017 (PNAR, 2018), the country is still far from achieving rice self-sufficiency.

The performance of rice farmers is urgent to be enhanced to promote the productivity and rice yield. According to the existing literature, credit access is an important factor for farmers' performances in Senegal (Fall, 2008). Access to financial resources enables farmers to get enough inputs and likely reach high productivity. However,

up to the present, credit access is one of the major weaknesses that inhibits agricultural development in Senegal. The available credit system lags behinds the rapid increasing demand of farming households. Particularly, rice production in Anambe basin is plagued with limited access to credit. Eventually, that makes it difficult for farmers to access adequate inputs and adopt modern agricultural innovations. Therefore, this study intends to shed light on the impact of access to agricultural credit on rice productivity in Senegal with the data collected from the irrigated area of Anambe basin.

There are some researches on the impacts of credit access on productivity. However, the impacts of credit access on agriculture productivity and technical efficiency in Senegal are not clear enough in present literature. Scholars have abstractly and empirically examined how credit access is vital for producers' performances in the agricultural sector. Iqbal et al. (2003), Rahman et al. (2014), and Owusu (2017) provided empirical evidences for the existence of positive effects of credit on agricultural production. Also, Seck (2018) applied endogenous switching regression model to examine the heterogeneous credit constraints and small farming holders' productivity in Senegal. The results indicated that credit constraints hinder farmers' production performance. Sjah et al. (2003) and Wicaksono (2014) also got the similar conclusions and pointed that agricultural credit has stronger influences on the intensified farming. Enyim et al. (2013), applied the unit-root cointegration to investigate the relationship between banking sector credits and agricultural activities in Nigeria. Their results suggested that credits supplied to farmers have positive relationship with their productivity. Agunuwa et al. (2015) applied time series to study the influence of commercial bank credit on agricultural productivity and pointed out that there is a positive impact of commercial bank credit on agricultural productivity. Moreover, findings in present studies suggest that there are more constraints, such as market imperfections, break-down of fertilizer supply and weaknesses of credit system in the process of investigation the access to credit. And Rezitis et al. (2003) highlighted that, besides agricultural credit, other factors, such as better use resources, information and better management should be adopted in order to improve technical efficiencies. Those researches provide the useful covariates in our models.

However, the results from Reyes et al. (2012) and Mghenyi (2015) show that the access to credit does not improve the agricultural productivity as credit is allocated to inputs that are already sufficient. Despite the existence of myriad studies on agricultural credit and its effect on productivity, the topic remains largely unexplored in Senegal. Furthermore, the literature on rice production with respect to credit access is scarce and this would hinder the complement of cogent policies in rice production.

To fulfill this research gap, this study tries to link rice production with agricultural credit access and scrutinize the impacts of agricultural credit access on rice farmers' productivity and technical efficiencies in the Anambe basin with the use of SFA model. The results of present study are highly essential for policymakers as they provide strong empirical evidence for the policy formulation and implementation to warrant the increase of rice productivity. The remainder of this paper is structured as follows: Section 2 presents the material and method, Section 3 displays the results and presents the discussion, and Section 4 shows the conclusion and recommendation of the study.

2. Material and Method

2.1 Data and Variable Definition

The data used in the study come from a household survey that was conducted in Anambe basin of Senegal in June and July of 2019. Anambe locates in Upper Casamance in the Kolda region which covers an area of 110,000 ha (watershed) with nearly 55,000 ha arable land suitable for irrigated crops. And there are 5 rural communes (Kandia, Saré Coly Sallé, Bonconto, Sinthiang Koundara, Ouassadou, Médina Chérif) and two communes (Kounkané and Diaobé-Kabéndou). A two-stage sampling procedure was adopted in the survey. In the first stage, Anambe villages were conveniently selected given it is one of the famous rice production areas with prevalence of agricultural credit access. In the second stage, 260 farmers were randomly selected using household lists obtained from the Society for Agricultural and Industrial Development in Senegal (SODAGRI). It was a door to door survey using a participatory research approach, and the pretested questionnaires were administered to households by well-trained enumerators. The data are composed of the quantity of rice production, amount of land used, amount of chemical fertilizers, quantity of seeds, labor availability, hired machine, a dummy variable of agricultural credit receipt, and some important socioeconomic and demographic variables. A summary of variables description is presented in Table 1. Stata 15 and Excel were used to analyse the data.

Table 1. Variables description

Variable	Definition
Yield	Quantity of rice produced in tons per hectare
Seed	Amount of seed used in tons per hectare
Labor	Amount of labor used includes own labor involved (hours per hectare)
Pesticide	Amount of pesticide used in liters per hectare
Herbicide	Amount of herbicide applied in liters per hectare
Hired_machine	Amount of machine used in hours per hectare, including both hired and farmer's machinery
Fertilizer	Amount of fertilizer (Urea and NPK) used in tons per hectare
Credit_received	Dummy for credit access, 0 = no credit received and 1 = credit received
Age	Age of the respondent: number of years
Gender	Dummy variable, 0 = female and 1 = male
Education	Dummy for educational status, 0 = illiterate and 1 = literate
Training	Dummy for training in rice cultivation, 0 = no training received and 1 = received training
Marital_status	Marital status of the respondent, 0 = single and 1 = married
Ethnicity	Ethnics of the farmer, 0 = Fulani and 1 = others
Farming_experience	Number of years in rice cultivation
Organisation_member	Organization membership, 0 = no and 1 = yes
Family_size	Number of people in the household
Irrigation_cost	Cost of irrigation in XOF per hectare
Rice_variety	Seed quality, 0 = non-improved seed and 1 = improved seed
Tenure_syst	Land tenure system, 0 = own land and 1 = rented land

2.2 Model Specification

Stochastic Frontier Analysis (SFA) was used to assess rice productivity and examine the effect of access to agricultural credit on the efficiency of rice production in Anambe basin (Senegal). SFA is a parametric technique that uses standard production functions, such as Cobb-Douglas production function and Translog production function, and explicitly considers the maximum feasible output level for a given set of inputs. It is used in modeling functional relationships with theoretical bounds such as: 1) modeling cost functions and analyzing cost efficiency, 2) modeling production functions and analyzing production efficiency, 3) modeling revenue functions and analyzing revenue efficiency, etc. That analysis tool was proposed by Aigner et al. (1977) and Meeusen et al. (1977) which involved a production function with an error term. The error term is consisted of two components—one is random effect (measurement errors and other random factors such as weather, strike, luck, etc.) and the other is technical inefficiency. It has been used in a vast number of empirical applications and extended in a number of ways. Following Battese et al. (1995), the SFA production function is as follows:

$$y_i = x_i\beta + v_i - u_i\,;\, i = 1, 2, \ldots N \tag{1}$$

Where, y_i is logarithm of output for farmer i^{th}, x_i is $k \times 1$ vector of logarithms of inputs for farmer i^{th}, β is a vector of unknown parameters, v_i is random variable assumed to be an iid $N(0,\sigma_v^2)$ and u_i is inefficiency error term which is a non-negative random variable associated with technical inefficiency of production and assumed to be independently distributed, such u_i is obtained by truncation (at zero) of the normal distribution with mean $z_i\delta$ and variance σ_u^2, z_i is a $p \times 1$ vector of variables that are assumed to have influences the technical efficiency and δ is an $1 \times p$ vector of parameters to be estimated. The technical inefficiency effect u_i can be modeled as:

$$u_i = z_i\delta \tag{2}$$

The variables which explain the extent to which the production of i^{th} farmer fall short of the corresponding stochastic frontier production value $(x_i\beta + v_i)$ are included in the inefficiency model. With the production function, technical efficiency of farmer i^{th} can be estimated as the ratio of observed output to the potential output defined by the frontier function. Formally, technical efficiency of farmer i^{th} is:

$$TE_i = \frac{y_i}{\exp(x_i\beta + v_i)} = \frac{\exp(x_i\beta + v_i - u_i)}{\exp(x_i\beta + v_i)} = \exp(-u_i) \tag{3}$$

Taking the input variables into consideration, the specified empirical SFA production function is as follows:

$$\begin{aligned} ln(Yield) = {} & \beta_0 + \beta_1 ln(Seed) + \beta_2 ln(Labor) + \beta_3 ln(Pesticide) + \beta_4 ln(Herbicide) \\ & + \beta_5 ln(Hired\_machine) + \beta_6 ln(Fertilizer) + (v_i - u_i) \end{aligned} \tag{4}$$

All the coefficients β are expected to have a positive sign (except for β_0 whose sign cannot be expected a-priori) which means a positive relationship between the quantity of inputs and the output.

The empirical regression on technical inefficiency component u_i is as follows:

$$u_i = \delta_0 + \delta_1(Credit\_received) + \delta_2(Gender) + \delta_3(Age) + \delta_4(Edu) + \delta_5(Train) + \delta_6(Marit\_status) + \delta_7(Ethnicity) + \delta_8(Farming\_exper) + \delta_9(Org\_member) + \delta_{10}(Family\_size) + \delta_{11}(Irrig\_cost) + \delta_{12}(Rice\_variety) + \delta_{13}(Tenure\_syst) \quad (5)$$

The SFA model was estimated by using the FRONTIER 4.1 software which is based on the Three Step Estimation Methodology proposed by Coelli et al. (1996): (1) Ordinary Least Squares (OLS) estimation of the function are obtained; (2) a two-phase grid search for $\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$ which ranges from zero to one is conducted with the β parameters setted to OLS values (except β_0) and the $\beta_0 \& \sigma^2$ parameters are adjusted according to Corrected OLS presented in Coelli et al. (1996); (3) the values selected in the grid search are used as starting values in an iterative procedure (using the Davidon-Fletcher-Powell Quasi-Newton Method) to obtain final MLE estimates.

3. Results and Discussion

3.1 Descriptive Statistics

Prior to the interpretation of the model estimation, the descriptive analysis of factors, including gender, age, ethnicity, rice variety used, marital status, organization membership, education level, training and farmers' financial status etc., were presented in Table 2.

Table 2. Summary statistics

Table 2A

Variable	Obs.	Mean	Std. Dev.	Min	Max
Age	260	40	8.36	25	62
Family_size	260	12	5.36	3	34
Farming_experience	260	12	8.17	2	40
Farm_size	260	1.82	3.76	0.25	50
Loan obtained	140	399809	321291.80	80000	3400000
Loan demand	140	460405	485161.20	100000	4500000

Table 2B

Variable	Obs.	Mean	Variable	Obs.	Mean
Gender			*Tenure_syst*		
Female (%)	85	32.69	Owned (%)	51	19.62
Male (%)	175	67.31	Affected (%)	209	80.38
Education			*Rice_variety*		
Literate (%)	120	46.15	Improved seed (%)	231	88.85
Illiterate (%)	140	53.85	Non improved (%)	29	11.15
Training			*Credit_received*		
No (%)	24	9.23	No (%)	76	29.23
Yes (%)	236	90.77	Yes (%)	184	70.76
Marital_status			*Sufficient_among_credit*		
Married (%)	238	91.54	No (%)	64	34.78
Single (%)	22	8.46	Yes (%)	120	65.21
Ethnicity			*Obtain_loan*		
Fulani (%)	215	82.69	Difficult (%)	83	45.10
Other (%)	45	17.31	Easy (%)	94	51.08
Organization_member			Very difficult (%)	7	3.80
No (%)	97	37.31			
Yes (%)	163	62.69			

Note. Loan demanded and Loan obtained by farmers are measured in Senegalese currency (XOF).

The average age of farmers in the study is 40 years, with the range of 25-62 which covers most of the active farming age. Thus, given the focus of the investigation, the sample comprises of an ideal group. In terms of gender, most surveyed farmers are males (67.31%) while female farmers account for 32.69%. This finding is consistent with the typical setups in rural Africa where most households are dominated by males. Interestingly, 62.69% of Anambe farmers in our survey belong to a cooperative as cooperatives serve them cardinal information and knowledge related to farming activities. Regarding seed adoption, 88.85% of farmers use improved rice seeds, while 11.15% resort to non- improved seeds. The finding presents remarkable progress for rice farmers and the country as improved seeds hold a great potential to increase productivity. Since Anambe basin comprises of small-scale farmers (average of farm size is 1.82 ha, with the range of 0.25 to 50 ha), use of improved seed is possible without credit access. However, for the large-scale farmers, the cost of improved seeds becomes a challenge in adoption.

According to the data, the proportion of married farmers is higher. Generally, the married households are large size households, there are 12 persons per household on average. It provides additional labor for households in farming and ultimately saves labor costs. More revelations indicate that 90.77% of famers are trained in rice cultivation. The proportion of illiterate farmers is of 53.85%, while those having formal education account for 46.15%. Thus, the high proportion of illiteracy might deter training and production performance.

Finally, 70.76% of the farmers received credit from Agricultural Credit Bank of Senegal (CNCAS). 51.08% revealed that it is easy to obtain loan from the bank while the rest claimed that it is difficult. On the other hand, 34.78% of farmers who received credit reported that they did not obtain enough credit as they demanded. Figure 1 shows a gap between farmers' financial demand and agricultural credit supplied by CNCAS (Agricultural Credit Bank of Senegal). Also, it has important implications for policymakers to find other avenues that would make credit access in agriculture sufficient.

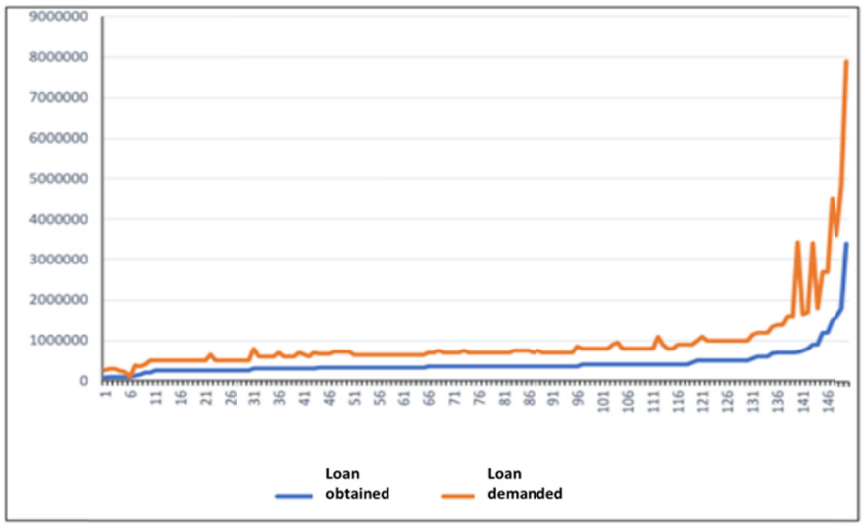

Figure 1. Loan demanded and money obtained by farmers in Anambe basin of Senegal

Note. The figures are based on the data collected during the household survey.

3.2 Technical Efficiency in Rice Production in Anambe Basin

The results of the stochastic frontier model are presented in Table 3. The results indicate that labor, pesticide, herbicides and fertilizer positively and significantly affect the rice productivity in the Anambe basin. Particularly, the coefficient of labor is significant at 1% with a positive value of 0.23. This implies that 1% increase of labor would increase the farmers yield by 0.23%. This result corroborates the findings from Nosiru (2010) that farmers with larger household size were more productive than those with small household size. In fact, large size households have more labor inputs. Similarly, use of pesticide was significant at 1%, with a positive value of 0.27. This result indicates that the use of pesticide is paramount in rice production in the study area. This result is also consistent with the findings from Sjah et al. (2003) that the use of pesticide contributes to intensification and improvement of farmers' production. Also, the use of herbicide is crucial in helping rice farmers to keep satisfactory performances. Its coefficient is statistically significant at 1% with a positive value of 0.04. Lastly,

fertilizer significantly affects the rice productivity in the Anambe basin. Its corresponding coefficient is significant at 1% with a positive value of 0.21. This signifies that the use of 1% more fertilizer by farmers would increase the rice output by 0.21%. This is also consistent with the research conclusions of Jiang et al. (2017) who provided evidence that the use of fertilizers in the rice production significantly yields positive outcomes.

On the other hand, hired machine is negatively correlated with the rice productivity but not significant. The use of machine in the rice production might be a poor substitution of manpower in the Anambe basin. The coefficient of seed is also not significant in the model.

Table 3. Maximum likelihood estimates of the stochastic frontier function

Variables	Parameters	Coef.	Std. Err.	P-Value
Cons	β_0	-0.880	0.282	0.002***
lnSeed	β_1	-0.014	0.040	0.722
lnlabor	β_2	0.231	0.064	0.000***
lnPesticide	β_3	0.271	0.038	0.000***
lnHerbicide	β_4	0.047	0.014	0.001***
lnHired_machine	β_5	-0.002	0.025	0.951
lnFertilizer	β_6	0.220	0.030	0.000***

Note. *** Significance at 1%; ** Significance at 5%; * Significance at 10%.

The inefficiency model was estimated with main influential variables and the results are listed in Table 4. There are some important technical efficiency determinants, including agricultural credit, gender, education, ethnicity, irrigation cost, rice variety, and land tenure system, which the Senegalese government should focus on to boost rice productivity.

The access to credit for farmers has a substantial effect on rice production inefficiency. The coefficient of credit is -0.038 and significant at 10% level. This suggests that agricultural credit access would decrease rice production inefficiency. This result is consistent with the results from Sjah et al. (2003) and Wicaksono (2014). Ethnicity is significant at 10% that means Fulani are more inefficient in rice cultivation than other ethnics in Anambe area.

On the other hand, the coefficient of gender is of 0.031 and significant at 5%, indicating that male farmers are less efficient in rice production. Fall (2008) and Diagne (2002) also found the rice production of female farmers is higher than that of male farmers. Similarly, the rice farmers' literacy has significant impacts on inefficiency reduction. In fact, educated farmers are more efficient than those who were not (Akyina et al., 2015). Tenure system represents another important determinant of rice production inefficiency. Its coefficient is negative and significant, namely, farmers who own the land are less efficient in rice cultivation probably due to weak awareness of land cost.

Lastly, the seed quality is an essential factor in the technical inefficiency model. The use of non-improved seeds has significant adverse effects on the rice production and would reduce rice production efficiency. This result is consistent with the findings of Sjah et al. (2003) who pointed out that the use of improved seeds is a necessary input to boost the rice production through intensification.

Table 4. The results of inefficiency estimation model

Variables	Parameters	Coef.	Std.Err.	P-Value
Cons	δ_0	0.197	0.293	0.502
Credit_received	δ_1	-0.038	0.022	0.082*
Gender	δ_2	0.031	0.015	0.048**
Age	δ_3	-0.001	0.001	0.615
Education	δ_4	-0.086	0.009	0.000***
Training	δ_5	-0.0011	0.024	0.964
Marital_status	δ_6	-0.007	0.025	0.764
Ethnicity	δ_7	0.033	0.019	0.079*
Farming_experience	δ_8	0.001	0.001	0.661
Organisation_member	δ_9	0.010	0.019	0.61
Family_size	δ_{10}	-0.001	0.002	0.675
Irrigation_cost	δ_{11}	0.0002	0.0006	0.473
Rice_variety	δ_{12}	0.040	0.023	0.087*
Tenure_syst	δ_{13}	-0.035	0.010	0.000***

Note. ***significance at 1%; **Significance at 5%; *Significance at 10%.

3.2 Agricultural Credit Access, Technical Efficiency and Rice Yield

To shed light on the detail impacts of access to agricultural credit on technical efficiency of rice production, we also show the distribution of technical efficiency for both farmers with access to agricultural credit and farmers without credit access. Table 5 reveals a sharp difference between the two groups and provides a hint of the importance of access to credit. In fact, farmers with access to credit have efficiency scores above 0.5 and majority of them are distributed in the range of 0.9-1 which is obviously higher than their counterpart. Such evidence suggests policymakers should pay more attention to credit for the efficiency improvement in rice production.

Table 5. Technical efficiency distribution across different groups

TE Category	Percentage		
	Credit Access	Non-Credit Access	Pooled
< 0.5		11.84	3.46
0.5-0.59	3.26	14.47	6.54
0.6-0.69	10.33	23.68	14.23
0.7-0.79	15.76	9.21	13.85
0.8-0.89	20.65	31.58	23.85
0.9-1	50.00	9.21	38.08

We also conducted t-tests to validate whether the differences of technical efficiency and rice yields between different agricultural credit access groups (Table 6). The technical efficiency for beneficiaries is 0.856 on average (ranging 0.517-0.988), while non-beneficiaries get an average efficiency of 0.711 (ranging 0.305-0.966). This implies that there is a 0.145 technical efficiency gap in favor of beneficiaries, and the difference between two groups are statistically significant. The pattern is also similar in rice yield where credit beneficiaries have 37% higher yields than their counterparts and it is significant at 1% level. These results suggest that agricultural credit may be positively associated with both technical efficiency and rice yields.

Table 6. Differences in technical efficiency and rice yield between farmers with different credit access

Item	Agricultural credit access status	N	Mean (Std.Err.)	Difference	% Change
TE	Access	184	0.856 (0.008)	0.145 (0.018)***	20.39
	Non-access	76	0.711 (0.020)		
Rice Yield	Access	184	3.742 (0.045)	1.017 (0.075)***	37.32
	Non-access	76	2.725 (0.046)		

Note. *** Significance at 1%; ** Significance at 5%; * Significance at 10%.

4. Conclusion and Recommendations

As many African countries, Senegal has high level of rice consumption. However, the national rice production level is far from meeting the domestic demand largely due to the poor performance of farmers in rice production and productivity. Even the Senegalese government has undertaken the national rice self-sufficiency program to address the issue, the country still falls behind rice self-sufficiency. According to the existing literature, credit access is an important factor for farmers' performances in Senegal, but the picture of the impacts of credit access on rice production is still not clear enough. Therefore, the present study investigated the effect of agricultural credit on rice farmers' productivity and efficiency with the data collected from the irrigated area of Anambe basin.

The results indicate that labor, pesticide, herbicides and fertilizer positively and significantly affect the rice productivity in the Anambe basin. The model also indicates that there are some important technical efficiency determinants such as agricultural credit, gender, education, ethnicity, irrigation cost, rice variety, and land tenure system have strong influences on the technical efficiency of rice production in Senegal. Particularly, the coefficient of credit is -0.038 and significant at 10% level, implying the agricultural credit access would decrease rice production inefficiency. The technical efficiency for credit beneficiaries is 0.856 on average which is higher than the average efficiency of 0.711 for non-beneficiaries. Furthermore, credit beneficiaries have 37% higher rice yields than their counterparts.

The policy implications of these findings are that agricultural credit allows farmers to decrease their technical inefficiency in rice cultivation. The government could set up policies to improve the technical efficiency of rice production by supporting better access to credit. More education programs for rice farmers and empowering women farmers would also be helpful for the production improvement. It is also necessary to provide farmers improved seed in order to increase their efficiency.

There are some limitations in present study. Firstly, only TE of farmers in the irrigated area of Anambe basin was evaluated. Secondly, the use of cross-sectional data does not support the assessment of the impact of agricultural credit over time. However, given the importance of staple rice to food security in Senegal, both farmers and government should take measures to improve the rice production performance and achieve rice self-sufficiency finally.

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