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Does Credit Influence Fertilizer Intensification in Rice Farming? Empirical Evidence from Côte D'Ivoire

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Abstract: In Côte d'Ivoire, the use of fertilizers in rice farming still remains low. Credit constraints have been frequently reported as the main reason hampering rice farmers from reversing this situation. However, there is no empirical evidence on the link between rice farmers' access to credit (AC) and fertilizer intensification (FI). This article examines this issue by using a sample of 600 rice farmers randomly selected in seven rice areas. Data are analyzed by the IV-Probit and IV-Tobit models. The results reveal that FI and AC reciprocally influence each other, implying that they are endogenous. An increase of credit by XOF 100 could increase the quantity of fertilizer used by 2.70 kg, all other things being equal. Moreover, FI and AC are strongly influenced by some socio-economic, rice farm, and institutional factors. Policymakers should take actions to facilitate rice farmers' access to credit and subsidized fertilizers. Other relevant explanatory variables should be considered in rice farming development policies. By providing empirical evidence of the link between rice farmers' access to credit and fertilizer intensification in Côte d'Ivoire, this paper contributes to the agricultural finance literature.

Keywords: agricultural credit; rice farming; fertilizer; instrumental variables; Côte d'Ivoire

JEL Classification: D24; D25; Q12; Q14

1. Introduction

Like many African countries, rice has become a commodity of strategic significance in Côte d'Ivoire. Currently, this cereal is the staple food of the population in both urban and rural areas of the country [1,2]. Thus, local paddy rice production must significantly increase in order to meet the increased rice demand for consumption. Côte d'Ivoire's paddy rice production is based on two production systems: the highland rice system (upland rice) and the lowland rice system (flooded rice and irrigated rice) accounted for 72% and 28% of the total rice area, respectively, in 2016 [3]. In upland rice farming (URF), rice is cultivated without soil surface flooding. For irrigated rice farming (IRF), rice is grown in lowlands with total or partial control of the water. The main sources of water for this type of rice farming are dams and diversion from rivers. Flooded rice farming (FRF) is performed in the floodplains. In this case, water is not controlled. The three rice farming system (RFS) can be grown nationwide.

In terms of yields per hectare, a relevant number of studies carried out in the country have shown that the paddy rice productivity at the farm-level is still low in Côte d'Ivoire [1–5]. The national paddy yield is 2.3 t ha^{-1} for all paddy rice production systems combined [3], while the average yields per hectare in some sub-region countries such as Mali range from 5.6 t ha^{-1} to 6.7 t ha^{-1} [6]. Although paddy rice production increases over the years, this increase is less proportional than the area cultivated.

Some researchers have reported that the low agricultural technology adoption (improved seeds, irrigation, fertilizers, tools) is one of the reasons for the yield gap [7]. Actually, in Côte d'Ivoire, the application of new agricultural technologies by rice farmers remains problematic. For instance, Doumbia et al. [1] found that the average quantity of fertilizer used is 89 kg ha^{-1} and 80 kg ha^{-1} for NPK and urea, respectively. This quantity is lower than the recommended quantity in the country (300 kg ha^{-1}) [8]. Doumbia et al. [1] also noticed that only 20% of rice farmers respected the recommended quantity. Recently, Kotchi et al. [2] found that only 39% of rice farmers applied fertilizers in the Divo area, in the southwest of Côte d'Ivoire. Regarding improved seed adoption, Saito et al. [3] reported a low rate (24%) of the adoption of the WITA 9 variety.

Previous studies have pointed out the lack of finance or the constraint of credit as one of the main reasons for the low use of improved agricultural technologies [9–11]. Indeed, farmers' willingness to apply improved varieties, fertilizers, and new agricultural technologies may be correlated to their financial capacity. In developing countries like Côte d'Ivoire, farmers' access to credit and input subsidies remains quite tricky, particularly for food crops [11]. However, in the country, the cost of inputs is high and represents the main cost of paddy rice production. For instance, fertilizer costs alone account for 21% of total paddy rice production cost [12]. Since the closure of agricultural finance banks, followed by the liberalization of the financial market in the country, most smallholder farmers are facing credit constraints [13]. In rural areas of developing countries, credit constraints have significant adverse effects on the adoption of new agricultural technologies and improved inputs, which in turn have an impact on farm output, farm profit, and farm investment [14,15]. Therefore, to invert this situation, easy access to credit should be implemented for smallholder farmers [11]. The availability and ease of access to credit are seen as the pathway to improve agricultural technologies' adoption, particularly in rural areas where smallholder farmers are too poor to accumulate savings.

Although credit constraints have been frequently reported as the main reason hampering rice farmers from adopting and extending agricultural technologies, to date, no empirical study has investigated the relationship between credit access and input intensification in Côte d'Ivoire's paddy rice production. Meanwhile, the question of how to stimulate local paddy rice production by strengthening the financial capacities of rice farmers remains topical. This concern is well established in the country's ongoing rice policy. Previous studies on paddy rice production in the country have mainly focused on the following aspects: the characterization of the different rice farming [1,4,10]; the adoption and extension of agricultural technologies [3,16,17]; the use of fertilizer [18] and its impact on yield [5,8]. This study attempts to give insight into the following question: Does credit allow Côte d'Ivoire's rice farmers intensify fertilizer utilization in paddy rice production? This paper empirically analyzes the influence of credit on fertilizer intensification in rice farming in Côte d'Ivoire.

Nevertheless, the adoption of agricultural technologies could determine the demand for credit due to the necessary costs of these technologies. Therefore, there may be a simultaneous causality between fertilizer intensification (FI) and access to credit (AC). The current study takes into account this by assuming the existence of reverse causality between FI and AC, which needs to be tested. We examine the determinants of FI and rice farmers' access to credit by applying a simultaneous equation system (SES). This approach is similar to that used by Carrer et al. [19] in different contexts.

Following Houssou et al. [20], we can define agricultural intensification as the action that makes agricultural systems more productive. Furthermore, because fertilizer is fundamental to enhancing productivity and it is the most widely adopted input in general and specifically in Côte d'Ivoire [21,22], in this study, we focus mainly on fertilizer among many other inputs. To the authors' knowledge, this is

the first study that empirically investigates the link between access to credit and fertilizer intensification in rice farming in Côte d'Ivoire. Thus, our investigations will provide a valuable contribution to the literature on financing smallholders.

The remainder of the article is divided as follows: Section 2 is focused on the review of some empirical studies. Section 3 deals with the theoretical framework, the methodology used in this study, and the summary statistics of the data. Empirical results and the discussion are presented in Section 4, while Section 5 concludes the research and provides policy implications.

2. Linkages Between Agricultural Technologies' Adoption and Credit

The neoclassical microeconomic theory assumes that farmers make adoption decisions based on the objective of utility maximization. A farmer will adopt technology when the utility of a new technology (U_n) exceeds the utility of a traditional technology (U_t). The adoption of new agricultural technologies leads not only to increasing productivity and food security, but also enhances agricultural development, while reducing poverty [7]. However, new agricultural technologies' adoption may demand high investment and increase farm operational costs [19]. Therefore, the availability of financial resources is a determining factor in the farmers' decision process [11,14].

Empirical studies carried out elsewhere have demonstrated that farmers without financial constraints invest more in improving agricultural inputs and are more prone to adopt and extend agricultural innovations. In Malawi, Zeller et al. [23] investigated the effect of participation in the credit program on hybrid maize and tobacco adoption. The authors found that participation in an agricultural credit program substantially raises the cropping share for hybrid maize and tobacco. Therefore, credit enables farmers to make the best choices in terms of crops. Tadesse [24] examined the relationship between fertilizer adoption and credit use in the southern highlands of Ethiopia. Tadesse's [24] estimation was based on instrumental variables' regressions to control the endogeneity of credit access and fertilizer adoption. The findings revealed that having access to credit positively influences the intensity of fertilizer use. In the same vein in Ethiopia, Abate et al. [25] reinforced Tadesse's findings by reporting that in comparison to farmers without credit, farmers with access to credit apply 24 kg more improved seeds and 51 kg more chemical fertilizer per hectare. Thus, access to credit improves the rate of adoption of agricultural technologies on the one hand and, on the other hand, positively influences the rate of application or intensification of this technology. In India, Narayanan [26] corroborated this assertion by reporting that credit access significantly increases input use. More specifically, a 10% increase in credit flow leads to a 1.7% increase of fertilizer (NPK) use, a 5.1% increase of pesticides, and a 10.8% increase in tractor purchases. Therefore, this sensitivity of inputs to credit flow highlights the link between credit and farmers' decision to adopt and intensify improved inputs.

Accordingly, we can assume that the lack of credit can be compared to the lack of a bridge to link two entities; on one side, smallholder farmers and, on the other side, the use of agricultural technologies. In this line, the studies of Croppendstedt et al. [27] and Simtowe et al. [28] showed that credit constraints impede fertilizer use in Ethiopia and the adoption of hybrid maize in Malawi, respectively. Increased availability of credit for farmers could allow them to intensify fertilizer use and the adoption of improved seed. In the Zanzibar region (Tanzania), the comparative study between smallholder farmers with credit constraints and smallholder farmers without credit constraints by Mohamed and Temu [29] showed that the effect of credit on adoption rate is more significant for credit-constrained farmers. By estimating empirically the returns to productive endowments for constrained and unconstrained households through a switching regression model, Guirkinger and Boucher [14] found that agricultural production in Piura would increase by 26% if all credit constraints were eliminated. Similarly, in Rwanda, Ali et al. [30] noticed that farmers who did not face credit constraints were the ones who more intensively adopted the modern inputs and technologies. Thus, we could infer that, when smallholder farmers have access to credit, they can increase the use of agricultural technologies. In rural Burkina Faso, Porgo et al. [11] examined farm households' cropland allocation

decisions under credit constraints by using a conditional mixed-process estimator to correct for the issue of endogeneity. The results showed that credit constraints negatively affect farm households' decision to allocate land to maize and cotton since these crops require more fertilizer than other crops (sorghum and millet).

Some previous studies have assumed that agricultural technologies' adoption and credit are mutually dependent [19,31]. This means that access to credit could lead to the adoption of agricultural technologies, and the adoption of technologies could also influence access to credit. Thus, both agricultural technologies' adoption and access to credit are treated as endogenous. However, by using a two-stage least squares (2SLS) model to overcome the endogeneity problem, Abdallah [31] found a one-way causal relation between agricultural technologies' adoption and access to credit in which credit positively influences agricultural technologies' adoption. In Brazil, the findings of Carrer et al. [19] reinforced the hypothesis of endogeneity between rural credit access and agricultural technologies' adoption by using a three-stage least squares (3SLS) to estimate an SES.

Although relevant studies, e.g., [11,19,25,26], in different regions of the world, have established the relationship between credit and agricultural technologies' adoption, it is imperative to recall that no empirical study in Côte d'Ivoire has investigated this issue, to the best of our knowledge. This study intends to fill this gap by focusing mainly on the link between AC and FI in paddy rice production.

3. Theoretical Framework, Methodology, and Data

3.1. Theoretical Framework

The theoretical importance of credit dates back to the pioneering studies of Schumpeter [32]. This author opined about the crucial role of credit for entrepreneurs in the adoption of new technologies. Early, underdevelopment was analyzed as the result of an investment deficit at both the macroeconomic and microeconomic levels. Therefore, to reverse this trend, several countries have adopted the Keynesian-inspired public financing model. These policies supported the intervention of the state in rural credit markets, which consisted of imposing directives to banks in the granting of directed credit programs in favor of agricultural investments. These approaches, qualified as neoclassical financial repression policies [33,34], were eventually confronted with sharp criticisms. It was later [33,34] theorized that state interventions that keep interest rates below their real level diminish the mobilization of savings; hence, the investment. Accordingly, they advocated financial liberalization for the development of banks and the financial market in developing countries.

The promoters of modern development theories argued that access to financial services boosts productivity and income, thus spurring economic growth [35,36]. In view of these theories, lack of credit is a major constraint to invest in productive and profitable activities. The proponents of financing constraints theory underlined that credit constraints negatively affect farm resource allocation and productivity [14,15]. Farmers that are quantity rationed in the credit market will under-invest relative to a credit unconstrained farmers. Accordingly, it is necessary to steer rural credit into productive projects and into the hands of the rural poor. Access to financial services is important to the operations of the agricultural sector. The poor in rural areas need much more capital than they save in order to sustainably invest in productive activities [11]. Credit provision by financial institutions could help to meet the excess in demand for capital. Following Schumpeter [32], credit is defined as a transfer of funds from savers to those who are in need of it. Access to credit would enable rice farmers to meet their legitimate needs and expand their opportunities. Based on the aforementioned analysis, we summarize the theoretical frame (Figure 1) of the present study as follows.
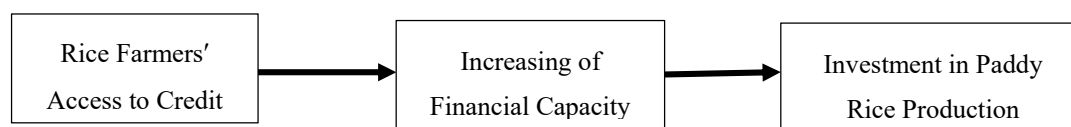

Figure 1. Theoretical framework.

3.2. Study Area and Sampling Design

The areas selected for this study were chosen on the basis of relevant criteria. In fact, in line with the new rice policy entitled national strategy for rice development (SNDR), the Ivorian territory has been divided into several rice development areas by the agency of rice farming development (ADERIZ: Agence pour le Développement de la filière Riz). ADERIZ is a state structure in charge of promoting the rice sector's development in Côte d'Ivoire. Based on this division, we selected seven areas (Figure 2). According to the last report of the national census of farmers and farms carried out by the Food and Agriculture Organization of the United Nations and Côte d'Ivoire's ministry of agriculture and rural development [37], agriculture is the main activity of the population in these areas, and all rice farming systems are practiced.
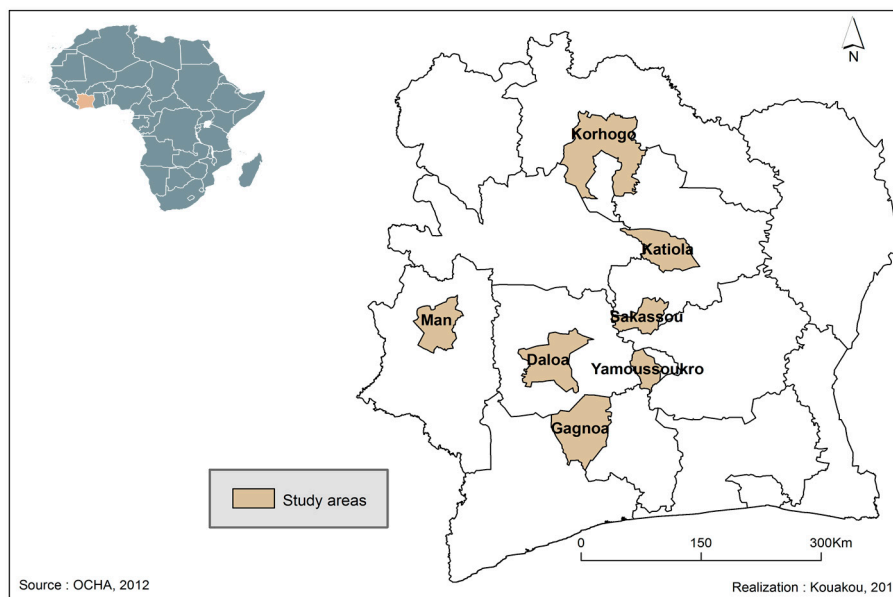

Figure 2. Map of the study area.

Data were collected from paddy rice farmers, using a semi-structured questionnaire and an interview. The sampling technique employed for data collection was the stratified two-stage random sampling method. At the first level, three villages were randomly selected in each study area. At the second level, the lists of paddy rice farmers in each village were used to select farmers. The lists of paddy rice farmers were obtained from their associations and extension organizations. Using the Yamane formula [38], as mentioned below (1), the size of the sample surveyed was set at 600 paddy rice farmers. The number of respondents per village was proportional to the size of paddy rice farmers in each area.

$$n = \frac{N^2}{1 + Ne^2} \tag{1}$$

where n is the sample size, N the population size, and e the level of precision (a 10% precision level was assumed). However, due to incomplete responses, only 588 fully filled questionnaires were used. Thus, twelve questionnaires were not exploitable.

3.3. Econometric Model Specification and Statistical Tests

The main motive of this study is to analyze whether rice farmers' access to credit affects FI. However, reverse causation between these two variables (AC and FI) remains a matter of concern. Rice farmers may intensify fertilizer use because of AC, and also, FI may justify the access and use of credit in rice farming due to an increase in investment needs. This simultaneity of causality results in an endogeneity problem between the two variables. Therefore, we used the instrumental variables (IV)

method, which is one common strategy to address endogeneity concerns [39,40]. The simultaneous causality between AC and FI is represented by the following SES:

$$FI = \gamma_1 AC + \psi_1 X + \lambda_1 Z_1 + \mu_1 \tag{2}$$

$$AC = \gamma_2 FI + \psi_2 X + \lambda_2 Z_2 + \mu_2 \tag{3}$$

where *FI* and *AC* are the proportion of fertilizer and access to credit, respectively. *X* is the vector of exogenous variables common to Equation (2) and (3); Z_1 and Z_2 are instruments for IV estimation of the first and second equations, respectively. γ_1, γ_2, ψ_1, ψ_2, λ_1, and λ_2 are the parameters to be estimated. μ_1 and μ_2 are the errors terms, which are independent and identically distributed (iid) with $(0, \sigma^2)$: $\mu \sim N(0, \sigma^2)$.

The proportion of fertilizer (*FI*) is computed as follows:

$$FI = \frac{q}{S * Q} \begin{cases} q = quantity\ in\ kg\ of\ fertilizer\ used\ by\ farmer \\ \quad S = size\ of\ rice\ farm\ in\ hectares\ (ha) \\ \quad Q = quantity\ in\ kg\ ha^{-1}\ recommended \end{cases} \tag{4}$$

As mentioned earlier, in Côte d'Ivoire, the quantity of fertilizer (NPK + urea) recommended is 300 kg ha^{-1}.

This study has two dependent variables: one is the proportion of fertilizer used by the rice farmer, which is a continuous variable, but truncated between 0 if the farmer does not apply any fertilizer and 1 if the farmer respects the exact quantity recommended; the other one is a dichotomous variable, that is whether the rice farmer has access to credit or not. Therefore, we employed the IV-Tobit (Equation (2)) and IV-Probit (Equation (3)) models developed by Newey [40] to estimate each equation of the SES.

Some statistical tests are essential to check the relevance and exogeneity of instruments. Indeed, both equations must be identified, i.e., each vector Z_1 and Z_2 must contain at least one instrumental variable that is exclusively correlated with *FI* and *AC*, respectively. The variables in vectors Z_1 and Z_2 must be exogenous, i.e., uncorrelated with both μ_1 and μ_2. Three tests, the Lagrange Multiplier (LM) test version of the Anderson [41] canonical correlation, the Sargan [39] test, and the Stock and Yogo [42] test, were used to check the identification of equations, whether the instruments were uncorrelated with the error term, and the instruments' strength, respectively. A rejection of the null hypothesis (H$_0$) in the LM test means the equations are identified, while a rejection of H$_0$ in the Sargan [39] test casts doubt on the validity of the instruments. Finally, if the value of the F-statistic exceeds the threshold that Stock and Yogo [42] provided, we can say that our instruments are strong, i.e., they satisfy the relevant conditions. Stata (ver. 14.0, StataCorp) was used for the estimations.

3.4. Variables and Empirical Hypotheses

Three groups of variables are defined and described in Table 1.

Table 1. Description of variables and the statistics' summary.

Variables	Description	Mean	SD
Endogenous variables			
Fertilizer intensification (FI)	Proportion of fertilizer	0.45	0.38
Access to credit (AC)	1 if access to credit; 0 otherwise	0.60	0.49
Common exogenous variables			
Gender	1 for male and 0 for female	0.86	0.34
Education	1 for primary and secondary school; 0 otherwise	0.55	0.50

Table 1. *Cont.*

Variables	Description	Mean	SD
Off-farm income	1 if practice of off-farm income-generating activities; 0 otherwise	0.24	0.43
Household size	Number of people	7.33	3.88
Experience	Number of years	15.08	8.16
Extension services	1 if access to extension services; 0 otherwise	0.51	0.50
Instruments for FI			
Farmer-based organization (FBO)	1 if belonging to FBO; 0 otherwise	0.63	0.48
Farm size	Rice farm size in hectares	1.14	0.94
Rice farming system (RFS)	1 if lowland rice farming; 0 otherwise	0.58	0.49
Cost of other inputs	In West African CFA franc (XOF)	67,563.5	60,668.6
Instruments for AC			
Distance	Distance between lender and borrower in Kilometer	15.13	12.53
Interest rate	Value in percentage	15.50	6.31
Land tenure	1 if owner of land; 0 otherwise	0.70	0.46

Source: survey results; SD = standard deviation; 1 XOF = 0.0017$ at the time of the interviews.

Endogenous variables: The main hypothesis of this study is that rice farmers' access to credit enables them to intensify fertilizer in paddy rice production. Indeed, as mentioned and explained theoretically, credit improves rice farmers' financial capabilities. The release of financial constraints could allow rice farmers to adopt agricultural technology in its entirety as recommended. Nevertheless, we should also consider the reverse causality hypothesis, i.e., the effect of FI on AC. Therefore, in this study, FI and AC are the two endogenous variables.

Common exogenous variables: The variables such as gender, educational level, household size, off-farm income, and extension services are used as common determinant variables of FI and AC (vector *X* in SES). The variable gender refers to the sex of the rice farmer. In the literature, Nahayo et al. [43] found that male farmers are more likely to apply agricultural technologies, while Degefu et al. [44] and Mansaray et al. [45] found the opposite result. Regarding the access to credit, Tadesse [24] reported that male farmers have a high probability of AC compared to female farmers. However, recently, the findings of Ouattara et al. [13] reported that female farmers have higher AC compared to male farmers. The level of education is a proxy of human capital. According to the literature, the educational level is an important determinant in the adoption of new agricultural technology [45,46]. Farmers with a higher education level may understand the necessity of adopting agricultural innovations. Furthermore, in Côte d'Ivoire, Ouattara et al. [13] found that a high level of education positively influences farmer's access to credit. Thus, this variable was expected to influence FI and AC positively. The variable off-farm income refers to the income generated by rice farmers from other sources of activities that are not related to farming. Based on the previous studies, off-farm income-generating activities increase farmers' financial capacity, resulting in a release of financial constraints [43,47]. Therefore, these farmers may deal easily with some agricultural costs compared to those who do not have off-farm income activities. In addition, the income from other sources independent of agricultural activities also increases the probability of farmers' access to credit [13]. Hence, this variable is expected to be positively correlated with our endogenous variable (FI and AC). The extension service variable focuses on whether rice farmers receive advice and visits from extension agents in their fields. Extension agents are those who teach farmers about the importance of agricultural technologies and innovations in rural areas. Previous studies have highlighted the positive influence of this variable on the adoption of agricultural technologies [48]. Moreover, agricultural extension agents are important sources of information for many rural farmers. These agents can also guide and direct farmers to a source of credit [31]. Therefore, this variable is expected to influence FI and AC positively. The household size refers to the number of people living in the household. Based on the literature, household size could positively or negatively influence fertilizer adoption. In Nigeria, Onyeneke [47] reported a

positive influence of household size on fertilizer use, while Theophilus [48] found that a large size of family decreases FI. As regards to AC, Sekyi [49] reported that the large size of the family decreases the AC. The experience variable represents the number of years a rice farmer has been growing rice. This variable is also a proxy of the rice farmer's human capital. In fact, it emphasizes the skill or knowledge of rice farmers in paddy rice production. The influence of the experience variable could be observed in two directions. Experienced rice farmers may be aware of the importance of agricultural innovations; therefore, they could respect the technology recommendations [47,48,50]. However, experience is often correlated with rice farmer's age; more experienced farmers might well be more risk-averse and less prone to face a change [43,46]. Experienced farmers may also have a good reputation with credit lenders [51]. This can increase their probability of AC.

Instrumental variables (IVs): To estimates the SES, IVs are required for both endogenous variables. Hence, for the endogenous variable FI, we used four instruments (farmer-based organization, farm size, rice farming system, and cost of other inputs). For the endogenous variable AC, three instruments were retained: distance, interest rate, and land tenure. The farmer-based organization (FBO) acts as a social network, where they share good farming methods with each other. Some studies have reported the positive correlation between FBO and agricultural technologies' adoption [44,50,52]. Therefore, FBO is expected to increase the likelihood of FI. The farm size refers to the size of the rice farm. The expected sign of this variable is unclear. Indeed, Ali et al. [50] found that the farm size and FI are negatively correlated in Ghana. Meanwhile, Haider et al. [21] found a positive correlation between farm size and fertilizer application rate in Burkina Faso. The RFS refers to the rice production system (rice farming in low or dry land). Earlier studies have mentioned that for ensuring high yield, lowland rice, especially the IRF, needs more fertilizer compared to URF. Therefore, rice farmers involved in IRF may use more fertilizer than those in URF [10,53]. Other studies argued that the use of fertilizer is reduced when crop rotation is made since this agricultural system improves soil fertility [54]. Moreover, Kinuthia et al. [55] reported that farmers' investment decisions in farming systems are influenced by climate change factors such as droughts and floods. Therefore, RFS could also be used to capture the effect of climate change on rice farmers' decisions. The cost of other inputs is related to the other costs that paddy rice production involved (labor, plowing, seed, weeding costs, etc.). The cost of these inputs increases rice farmer's agricultural expenses [56]; thus, these costs are likely to negatively influence FI.

As regards the instruments for AC, the distance is a proxy variable of transaction costs, such as transport costs. This variable is expected to be negatively correlated with AC. Indeed, the distance between lenders and borrowers is positively correlated with the cost of transport paid by both (lender and borrower) for visits. Previous studies have reported a negative effect of distance on AC [31,51]. The interest rate represents the credit cost. This cost is charged by lenders as a benefice of the loan and is paid by the borrower plus the initial amount of the loan during the reimbursement. Thus, other things being equal, if the interest rate charged by lenders is high, it could deter farmers from borrowing [57,58]. Nevertheless, some studies found that the interest rate does not necessarily affect borrower choice [14]. In fact, in rural areas, despite the high interest rate, a large number of borrowers choose informal credit because of several reasons (quick disbursement of credit, suitable reimbursement date, etc.). Thus, the correlation between the interest rate and AC could be positive or negative. The variable land tenure is a proxy of the land title (land ownership). The land title is often used as collateral by farmers to guarantee the credit [31,51]. Thus, being a landholder could increase the AC.

3.5. Descriptive Statistics

Table 1 summarizes the rice farmers' statistics. The results show that in Côte d'Ivoire, the average quantity of fertilizers applied per hectare is 45% of the recommended quantity. This finding indicates that fertilizers utilization rate in rice farming is markedly below 300 kg ha^{-1}. More specifically, the average quantity of fertilizer used is 135 kg ha^{-1}. The low proportion of fertilizer used in rice farming in Côte d'Ivoire has been mentioned in several studies [2,4]. A study by Doumbia et al. [1] reported

that the average quantity of fertilizer applied is 169 kg ha^{-1} in two major agro-ecological zones of the country (forest and savannah).

With regard to AC, the descriptive analysis revealed that 60% (*n* = 353) of rice farmers had AC during the survey year. Although more than half of rice farmers had AC from diverse sources of credit (formal and informal), 40% (*n* = 235) did not have AC. In a previous study, Ouattara et al. [13] reported that the rate of smallholder farmers who do not have access to agricultural credit is still high, precisely in the center-west of Côte d'Ivoire. The average interest rate of credits is 15.5% of the initial loan, and the average distance between rice farmers and lenders is 15.13 km.

With respect to the influence of farmer gender in paddy rice production, we found that Côte d'Ivoire's paddy rice farmers are predominantly males. More than four-fifths of respondents were males. This observation could be explained by the fact that, in Côte d'Ivoire, men are the legitimate heads of households. This result was in agreement with Riquet et al. [59], who reported that men are much more likely (90%) to be the head of a farming household in Côte d'Ivoire than women (10%). Concerning rice farmers' socio-economic characteristics, the results showed that the average number of people per household was 7, and Côte d'Ivoire's rice farmers have an average of 15 years' experience in rice farming. Few (24%) of them are involved in off-farm income-generating activities. In terms of landholding, seventy percent of rice farmers are landholders. Nevertheless, land ownership in Côte d'Ivoire remains customary in most cases and is bequeathed inherently [37]. Regarding the education level, fifty-five percent of respondents have at least primary and secondary school education level, while 45% have never been to school.

By analyzing the rice farm characteristics, we noticed that the average size of rice farms was 1.14 hectares, which highlights that Côte d'Ivoire's paddy rice production is held by smallholder farmers. Relating to the RFS, fifty-eight percent of the respondents were involved in lowland rice production; this includes flooded rice production and irrigated rice production. The rest of the respondents (42%) were involved in URF. Nonetheless, some rice farmers were involved in the two rice production systems during the survey year. Apart from the cost of fertilizer, rice farmers spend an average of XOF 67,563.5 in other inputs or activities related to paddy rice production such as plowing, sowing/planting out, seeds, weeding, and so forth.

Finally, the descriptive analysis of institutional factors showed that 51% of rice farmers received advice or visits from extension agents. Based on our results, it appears that 63% of rice farmers belong to FBOs.

4. Results and Discussion

4.1. Determinants of FI

The results in Table 2 present the determinants of FI in paddy rice production. As mentioned earlier, we checked the relevance and exogeneity of instruments for credit. Firstly, the under-identification test revealed that the instrumental variables are relevant; thus, the credit equation was identified. Secondly, the weak identification test showed that the instruments are strong. Finally, the over-identification test suggested that the instruments are jointly exogenous, i.e., they are not correlated with the error term in Equation (1). Therefore, we conclude that the instruments (distance, land tenure, interest rate) are relevant and exogenous. Furthermore, the Wald test of endogeneity x^2 was significant at 1% level, implying that the credit variable is endogenous, and therefore, it is essential to employ the IV-Tobit to estimate the model.

Table 2. Estimates for the dependent variable fertilizer intensification (FI): IV-Tobit.

Variables	Coefficients	SE	*p*-Value
Access to credit	0.027	0.004	0.000 ***
Gender	−0.150	0.062	0.016 **
Household size	0.008	0.005	0.145

Table 2. *Cont.*

Variables	Coefficients	SE	*p*-Value
Education	0.090	0.042	0.032 **
Experience	−0.005	0.002	0.025 **
Off-farm income	−0.000	0.051	0.991
Extension services	0.216	0.047	0.000 ***
Farm size	−0.021	0.019	0.270
Rice farming system (RFS)	0.383	0.105	0.000 ***
Cost of other inputs	−0.350	0.106	0.001 ***
Farmer-based group (FBO)	0.182	0.048	0.000 ***
Number of observation: 588 Prob > χ^2 = 0.000			
Wald test of endogeneity χ^2			10.82 ***
Under identification test (Anderson canonical correlation LM statistic)			565.957***
Weak identification test (Cragg–Donald Wald F-statistic)			4946.789
Stock-Yogo weak ID test critical values: 10% maximal IV size			22.30
Sargan statistic (over-identification test of all instruments)			2.904 ***

Significance levels: ** = $p \leq 0.05$ and *** = $p \leq 0.01$; SE: standard errors.

As shown in Table 2, there is a positive and significant influence of credit on the probability of FI. An increase of credit in XOF 100 could increase the quantity of fertilizer used by an Ivorian rice farmer by 2.70 kg, all other things being equal. This finding highlights the importance of credit in FI in paddy rice production in Côte d'Ivoire. Thus, the main hypothesis of this study is corroborated. Paddy rice production involves many costs from plowing to harvesting. If some costs such as sowing/ planting out, weeding, or harvesting costs can be eliminated by the rice farmer by doing these activities with the aid of family, this is not the case for necessary inputs for paddy rice production. Compared to other crops, rice farming requires intensive fertilizer use for a high yield. In Côte d'Ivoire, this input is the most used by rice farmers to enhance their productivity [22]. A previous study reported that the cost for fertilizer accounts for almost 21% of total paddy rice production cost in Côte d'Ivoire [12]. The financial capacity of rice farmers is often limited. Therefore, AC is a prerequisite for acquiring inputs. Our finding agrees with previous studies carried out elsewhere in the world. In Africa, studies by Abate et al. [25], Abdallah [31], and Porgo et al. [11] emphasized the positive effect of credit on agricultural technologies' adoption in Ethiopia, Sub-Saharan Africa (SSA), and Burkina Faso, respectively. The findings of Abate et al. [25] showed that credit enables farmers to apply 51 kg more chemical fertilizer per hectare than those who do not have AC. Similarly, Abdallah [31] found that the probability of agricultural technologies' adoption among farmers who have AC is 0.04 higher when compared to farmers who do not have AC. According to Porgo et al. [11], credit constraints compel smallholder farmers to allocate less land to maize and cotton crops since they cannot deal with the financial costs of fertilizer involved by these crops. In India, Narayanan [26] highlighted the importance of credit in agriculture modernization by reporting that a 10% increase in credit flow leads to a 1.7% increase in fertilizer (NPK) use. Recently, in South America, Carrer et al. [19] found that AC increases the probability of adopting integrated crop-livestock systems in the State of São Paulo, Brazil, by 37.5%.

Besides the credit, some variables such as gender, education, experience, extension services, FBO, RFS, and the cost of other inputs are also determinants of FI in Côte d'Ivoire (Table 2). Our results showed that the correlation between gender and FI is negative and significant at the 5% level. Based on our codification, this result is in favor of female rice farmers. Females involved in rice farming are more likely to use more fertilizer than male rice farmers, all else being equal. This may be explained by the fact that in Côte d'Ivoire, women rarely own a farm. Thus, the few women (14% of respondents) engaged in rice production are more likely to follow the recommendation in terms of fertilizers and other inputs needed for better yield as they expect good financial gain. This finding corroborates those

of Degefu [44] and Mansaray et al. [45], who found that female-headed households were more likely to adopt improved inputs, in comparison with male-headed households in Ethiopia and Sierra Leone, respectively. Nevertheless, this finding contradicts the study of Nahayo et al. [43], who reported that male farmers have more willingness to participate in crop intensification in Rwanda.

Rice farmers' educational level is significant (at 5% level) and positively influences FI in rice farming in Côte d'Ivoire. Rice farmers who have a high educational level are more likely to intensify the use of fertilizer compared to those with a lower educational level. Indeed, the most educated rice farmers can easily understand the importance of fertilizer in rice farming and apply it as recommended by researchers. The positive influence of a high educational level on the adoption of improved inputs has been reported in previous studies carried out in Sierra Leone [45] and Nigeria [46].

We documented that the farmer experience in rice farming is negatively significant at the 5% level. This means that the less experienced rice farmers are more likely to intensify fertilizer than more experienced rice farmers. One of the reasons for this finding may be explained by the fact that in Côte d'Ivoire, recently, rice has become a cash crop for many farmers following the price drop of other cash crops, especially coffee, cashew nut, and cocoa. Thus, farmers newly engaged in rice growing may intensify fertilizers to maximize their profits, resulting from better yield. This result is in line with some studies carried out elsewhere [43,46]. In Nigeria, Yusuf et al. [46] found that as the farmers get older, they become more averse to risk-taking in rice production technologies. Nonetheless, this result negates the findings of Theophilus [48], who reported that adequate experience in farming results in the intensification of fertilizer in maize production in Ghana.

We identified the rice farming system as a determinant of fertilizer intensification with a 1% the significance level. Rice farmers engaged in lowland rice production are more likely to intensify fertilizer than those who grow upland rice. This may stem from the fact that lowland rice production, particularly IRF, requests more fertilizer. This result is in accordance with previous studies conducted in Africa [53] and in Côte d'Ivoire, in particular [10]. In addition, in lowland areas, the soil is used continuously for rice farming at the same place. This practice gradually depletes the soil nutrients. Thus, the intensification of fertilizer is essential in maintaining soil fertility. In contrast, in the URF system, farmers can apply a crop rotation in the same area in sequenced seasons. This agricultural practice helps to increase soil fertility and agricultural production with a lower rate of fertilizer or without any fertilizer [54]. Furthermore, we could explain our finding by the fact that the presence of the irrigated system encourages rice farmers to take some risks in investing in fertilizer as the production and expected yield are more secure and less dependent on rain-fed agriculture. In Kenya, Kinuthia et al. [55] found that farmers invest more in crops in the presence of irrigation systems since they can manage water.

The relationship between extension services and FI was positive and significant at the 1% level. Rice farmers who receive advice or visits from extension agents are more likely to intensify fertilizer use. This is probably due to the fact that extension agents explain the importance of the recommended quantity of fertilizer to rice farmers. Especially in Côte d'Ivoire, extension agents are the primary source of information about the existence and merits of any new farming technology. They are rice farmers' counsellors in agricultural techniques and the adoption of inputs. This result is in line with Theophilus [48], who opined that regular contacts with extension agents are essential in enhancing the agricultural technologies' adoption.

It appeared that there was a positive and significant effect at the 1% level of having membership in a farmer-based organization on FI in rice farming in Côte d'Ivoire. In fact, FBO reinforces the farmer's social relations and allows them to exchange ideas and information about agricultural technologies. This is one reason why in Côte d'Ivoire, ADERIZ encourages rice farmers to join FBOs. This finding agrees with Degefu [44] and Ali et al. [50], who emphasized the importance of FBOs in agricultural technologies implementation in Ethiopia and Ghana, respectively. A recent study, in Côte d'Ivoire in the Belier and Gbeke regions, showed that information dissemination by rice farmers enhances the adoption of improved agricultural practice [52].

Based on our findings, the cost of other inputs negatively influences FI in paddy rice production at a level of 1%. The higher the cost of other inputs involved in paddy rice production is, the lower the probability of FI is. Although rice farmers can cope with some activities such as plowing and weeding with the aid of family members, extra labor is sometimes needed for some tasks, which increases production costs. Moreover, rice farmers must deal with the cost of seeds, herbicides, pesticides, etc. Therefore, they may adopt a technical substitution approach between the costs of other production factors and the costs of fertilizers according to their financial capacities. For example, in Côte d'Ivoire, a previous study reported that the rate of mechanical plowing was 100% for irrigated rice farming, and these costs were estimated at XOF 75,000 per hectare in [12]. In Laos, Newby [56] found that due to the high cost of inputs and labor, rice farmers in the rain-fed lowlands often adopt low-input systems with a low quantity of fertilizers.

4.2. Determinants of AC

The determinants of AC are presented in Table 3. The identification tests (under-identification test, weak identification test, and over-identification test) showed that the instruments for FI (RFS, farm size, FBO, and cost of other inputs) are relevant and exogenous. Moreover, the Wald test of endogeneity χ^2 was significant at the 1% level, meaning that the FI variable is endogenous; thus, the use of IV-Probit to estimate the model is warranted.

Table 3. Estimates for the dependent variable access to credit (AC): IV-Probit.

Variables	Coefficients	SE	*p*-Value
Fertilizer intensification	0.181	0.034	0.000 ***
Gender	1.268	0.722	0.079 *
Household size	−0.186	0.073	0.011 **
Education	0.107	0.045	0.018 **
Experience	−0.031	0.036	0.391
Off-farm income	0.457	0.744	0.538
Extension services	−1.320	0.848	0.120
Distance	−0.286	0.071	0.000 ***
Interest rate	−0.143	0.351	0.682
Land tenure	0.231	0.555	0.677
Number of observation: 588 Prob > χ^2 = 0.000			
Wald test of endogeneity χ^2			26.60 ***
Under identification test (Anderson canonical correlation LM statistic)			192.724 ***
Weak identification test (Cragg–Donald Wald F-statistic)			70.331
Stock-Yogo weak ID test critical values: 10% maximal IV size			24.580
Sargan statistic (over-identification test of all instruments)			5.445 **

Significance levels: * = $p \leq 0.10$, ** = $p \leq 0.05$ and *** = $p \leq 0.01$; SE: standard errors.

As indicated in Table 3, the probability of AC increases with the intensification of fertilizer, ceteris paribus. We could explain this finding in two ways. Firstly, rice farmers who apply more fertilizer may be those who promote financial support the most such as credit. Indeed, a large quantity of fertilizer in addition to the costs of other production factors could exceed the financial capability of the farmer, thus justifying the need for financial support. ADERIZ provides credit lines in the form of inputs such as fertilizers (NPK and urea), improved seeds, and durable equipment to some rice farmer-based organizations. Those who benefit from these credit programs must properly apply the above-mentioned inputs as recommended by local researchers. Secondly, the intensification of fertilizer may increase rice yield [22]. A high yield could increase rice farmers' income, which could facilitate the reimbursement of credits and therefore guarantee AC for the next agricultural season. These two arguments result in a reverse causality between FI in rice production and AC in Côte d'Ivoire. These findings are consistent with those of Carrer et al. [19], who confirmed the simultaneous relation

between credit and agricultural technologies' adoption in the State of São Paulo, Brazil. Nonetheless, our result negates the findings of Abdallah [31].

The AC of Côte d'Ivoire's rice farmers is also influenced by other factors. Gender influences positively and significantly the AC at 10% level. Male farmers are more likely to have AC than women. This may be ascribed to the fact that the paddy rice production in Côte d'Ivoire is dominated by male farmers. Thus, they are the first beneficiaries of financial supports provided by ADERIZ. Moreover, male rice farmers in Côte d'Ivoire are engaged in several other income-generating agricultural activities such as cash crops (cocoa, coffee, and cashew nut). These crops are often considered as collateral for credit lenders. A similar result has been found in Ethiopia [24]. This finding is contrary to Ouattara et al. [13], who reported that female farmers have more AC than their counterpart male farmers in Sassanda-Marahoué district, Côte d'Ivoire. However, the study of Ouattara et al. [13] focused on microfinance institutions' credit and did not take into account other rural credit sources in Côte d'Ivoire.

Our findings reveal that household size has a significant (at 5% level) and negative relationship with AC. As household size increases, the needs of the family increase. Therefore, a rice farmer with a larger household may divert a part of the loan to unintended purposes for the upkeep of their family. This result is consistent with a study carried out in Ghana [49].

We observed that education level was a significant and positive variable of AC at the 5% level. The probability of AC increases with the level of education, all things being equal. Undeniably, the high level of education is important human capital, which could enable farmers to accurately understand credit requirements compared to their counterparts with a lower educational level. Similar observations have been made by Twumasi et al. [51] and Ouattara et al. [13], who found that the excellent level of education is one of the key determinants of farmers' access to credit, respectively in Ghana and Côte d'Ivoire.

We also report that the distance between rice farmer and lenders, which is the proxy variable of transaction costs in this study, was significant at the 1% level and negatively correlated with AC. In fact, the further the rice farmer is from the lenders, the higher the transaction costs involved in credit in terms of transport costs. Therefore, this can result in the loss of earnings for the lender who decides not to grant the loan. Our result bears rich parallels to those of Abdallah [31] and Twumasi et al. [51], who found that transaction costs such as transport costs decrease the likelihood of farmer AC in SSA and Ghana, respectively.

5. Conclusions and Policy Implication

Despite the preponderant role of fertilizers in enhancing paddy rice yield, the quantities applied in rice farming do not meet the researchers' recommendation yet in Côte d'Ivoire. Rice farmers' credit constraints have been reported as one of the main reasons for this problem. Nonetheless, up to now, no empirical study has assessed this assertion. This study was undertaken to empirically investigate the link between AC and FI in rice farming in Côte d'Ivoire. Our findings indicate that both FI and AC reciprocally influence each other positively and significantly, implying that these two variables are endogenous. More specifically, an increase of credit in XOF 100 could increase the quantity of fertilizer used by 2.70 kg, ceteris paribus. Our study also reveals that FI is influenced by socio-economic (gender, education, and farmer experience), rice farm (RFS and cost of other inputs), and institutional (extension services and FBO) factors, similar to AC, which is influenced by some socio-economic characteristics (gender, household size, and education) and transaction costs such as distance between lenders and rice farmers.

Following these findings, first of all, we suggest that policymakers take steps to facilitate rice farmers' access to credit and subsidized fertilizers. ADERIZ should strengthen and extend its support for inputs and equipment to all rice farmers. For instance, special credit programs for agricultural inputs such as fertilizer could be implemented. These measures could reduce rice farmers' financial constraints and improve fertilizer adoption and intensification. Secondly, some variables should be

considered in rice farming development policies. Policymakers should reinforce extension services and the construction of irrigation infrastructures. Furthermore, we recommend the development of farmer-based organizations and the capacity building of these organizations. This could promote an inclusive rice policy for all rice farmers, especially those in remote areas. Moreover, the human capital of Ivorian rice farmers must be strengthened through literacy programs and agricultural training.

Our empirical results are limited to data gathered within a specific period. However, this study could contribute to agricultural finance policymaking, which remains relevant in developing countries, particularly in Côte d'Ivoire. Further research is necessary to clarify the determinants of credit demand and choice between different sources of credit by rice smallholder farmers in developing countries and specifically in Côte d'Ivoire.

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