Effect of Equipment Credit on the Agricultural Income of Cotton Producers in Mali

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

In Mali, lack of access to agricultural credit becomes a factor behind low farmer income and even rural poverty. However, agricultural credit is seen as a tool to increase production as well as farm income. The objective of this research is to evaluate the effect of equipment credit on the income of cotton producers in Mali. To this end, a survey was carried out among 400 producers in 2019, 127 of whom had had their equipment credit applications accepted, compared to 273 who had not had their equipment credit applications accepted. The survey was carried out in the areas of the Compagnie Malienne de Développement de Textiles (CMDT) of Fana and Koutiala in Mali. The method of analysis is the estimation of the instrumental variables multiple regression model of credit, implementing the estimation method of Heckman (1979) to account for the zero profit for 16% of the producers. The results of the econometric model estimates show that the variables that lead to an increase in income at the 5% threshold are: access to credit, quantity sold of cotton, costs of material goods used on the farm, total area sown, quantity sold of other crops, selling price of other crops. In other words, access to equipment credit could enable cotton producers to improve their income by 35%. Equipment credit entitles farmers to use more capital goods on the farm. This use of equipment increases agricultural productivity and yields, and in turn increases farm income. Based on these results, we can make some policy recommendations to boost cotton production, make other crops more beneficial to producers and grant more equipment credit.
Keywords: Equipment credit; heckman; instrumental variable; cotton producer; agricultural income; CMDT; Mali.

1. INTRODUCTION

From the end of the Second World War until the mid-1970s, rural finance policies in Mali were inspired by Keynesian economic theories: they were based on strong state intervention, known as the 'all-state' or 'welfare state', and focused on the function of 'agricultural credit'. Rural and agricultural underdevelopment was analysed as the result of the inability of poor peasants to save and invest; credit was then used as a 'development lever', necessary to initiate the 'virtuous circle' of development and private investment [1].

With the crisis of the 1970s, the Bretton Woods Institutions, within the framework of Structural Adjustment Programmes (SAPs), required countries to liberalise the agricultural credit sector, with the result that the state withdrew and the banks abandoned the rural environment. From 1980 to 2000, it was the neo-classical approach and the liberalisation of the economies of the South [2,3].

From the 2000s onwards, the previous approaches were challenged and institutional theory and imperfect information were introduced into development and poverty reduction issues. Each of these phases corresponded to public, private or mixed financial arrangements, and led to the renewal of the theoretical framework on financial markets [4].

Today, in order to modernise agriculture in Mali, policies have been put in place to address the low agricultural yields, such as the policy of subsidising tractors and fertilisers, to intensify agriculture, more specifically cereals and cotton, which have been chosen as high-stake sectors likely to increase farmers' income.

In Mali's cotton zone, access to finance is very limited outside the 'cotton system' and therefore concerns practically only the farms with the best production factors. For the 2019-2020 agricultural season, out of 79,000 farms in CMDT zones, only 1% have a working tractor. The average yield of cotton in 2018 is 395 kg/ha, whereas it was 3% higher in 1993 (IPC, 2019). As a factor justifying this low yield, Koné [5] points to the inadequacy of agricultural credit financing, which hinders producers in the use of agricultural inputs and equipment.

Despite these policies, many farmers do not have increased access to these subsidies; this is compounded by weak financing from banks and microfinance institutions that offer only 4% for the agricultural sector [6].

Yet, agricultural credit is seen as a tool to increase production as well as farm income (especially when provided in a timely manner), through better adoption of new technologies and use of improved agricultural inputs [7]. It serves as a catalyst that activates other factors of production and makes underutilised capacities functional for increased production (Ijere, 1998). As a result, lack of access to agricultural credit becomes a factor behind low farmer income and even rural poverty.

Despite all the policies of innovation and improvement of financing, the problem of financing the needs of producers is still present. This context is very worrying, especially since there is a positive correlation between access to credit and the adoption of new technologies, respect for good production standards, and in general agricultural performance and the well-being of producers [8]. In Mali, some authors have focused on agricultural credit in cotton areas (Konaté et al., 2002); [9,10]. However, they do not propose an approach to the effect of equipment credit on the income of cotton producers using econometric methods dealing with both the endogeneity of agricultural credit and the existence of non-profits for certain producers.

In view of this situation, this article seeks to answer the following questions: What is the level of agricultural equipment and agricultural productivity and why? What is the effect of medium- to long-term credit on the income of cotton producers?

The purpose of this work is to examine the effect of access to equipment credit on the income of cotton producers in the CMDT zones of Koutiala and Fana. The identification of the determinants of farm income will be based on a multiple linear model with instrumental variables of farm credit. This model will allow us to quantify the relationship between agricultural income,
agricultural credit, the characteristic variables of farm managers and production factors.

The literature review will be presented in the first section; the multiple linear instrumental variable model will be presented in the second section; the results will be presented and interpreted in the third section; and finally, some policy recommendations will be made.

2. LITERATURE REVIEW

2.1 Theoretical Arguments

The first need of the entrepreneur is a need for credit [11]: "Credit is essentially a creation of purchasing power with a view to its concession to the entrepreneur". It allows the acquisition of factors of production on credit. For Ramos [12], credit is the engine of the economy because it allows for mass production which, in turn, leads to a reduction in selling prices that ultimately benefits the consumer.

At the economic and social level, credit is an important provider of employment, not only for the financial sector as such, but indirectly for all the sectors it supports (as investment goods and/or production capacities and/or risk guarantees) such as industry, construction, etc. [8]. In addition to its economic function, credit also plays a social role (improving living conditions, coping with unforeseen events, building up reserves, etc.) [8].

Furthermore, the literature review contrasts two fundamentally different conceptions of access to formal credit as a factor of income improvement. Some authors (Kpadonou et al., 2010; [13-15]) conclude that farmers with access to formal credit appear to be technically more efficient, receive modern inputs, adopt coping and mitigation strategies to the effects of natural shocks, and respect agricultural calendars. For the case of China, Feder et al. [14] consider that increasing the supply of formal credit to a certain level causes diversion partly to consumption, so the likely effect on output will be smaller than that expected when all funds are assumed to be used productively. Labie [16] confirms this tendency by showing in his work that most poor people use their credit to solve social and non-productive problems. This in turn leads to the degradation of their productive activities and increases their poverty.

The second view is supported by other authors [2], (Anang et al., 2016); [17], (Sial et al., 2012).

They find no significant relationship between agricultural credit and agricultural performance. For them, differences in agricultural productivity are due to farmers’ characteristics and not to credit. Furthermore, they believe that access to agricultural credit rather increases production costs and yields are not improved. In fact, the credit management mechanism most often leads to delays in the implementation of inputs. This delay in the consumption of inputs at the appropriate time reduces expected yields. This increases costs and does not have the desired effect of increasing production and income.

2.2 Empirical Arguments

Several authors have studied the effects of credit on productivity and income, and the importance of these studies is explained by the fact that access to credit is often considered the main determinant of productivity and living standards in rural areas.

Luan et al. [18] in a study in Vietnam used the Propensity Score matching method to examine the impact of different credit sources on household income. They succeed in showing that overall rural credit plays an important role in improving household income. In addition, they argue that a well-functioning credit system must take into account variations in transaction costs, the disbursement system, loan characteristics and the typical socio-economic conditions of credit recipients.

In his study in Côte d’Ivoire on the measurement of the technical efficiency of food crop farmers, Ekou [19] used the production or cost frontier (deterministic or stochastic). He argued that economic efficiency includes technical efficiency and allocative efficiency, which need to be differentiated in the analysis of the determinants of agricultural performance. He showed that variables such as household size, access to extension and membership of an economic grouping improve the technical efficiency of producers in the study area.

In Burkina, Savadogo et al. [20] examined the supply response of farms to prices, and other farms to prices and other factors in the three agro-ecological zones of Burkina Faso from 1981 to 1985, and the total or aggregate supply response. Burkina Faso farmers grow four crops (millet, cotton, sorghum, maize). Following the dual producer approach, a supply function and input demand functions are derived from the
maximisation of the profit function (which is in this case in the form of a quadratic function). The results showed that the use of animal traction (equipment credit) allows an increase in yields, an increase in the area cultivated, an additional income linked to off-farm transport, a reduction in certain chores, and a long-term improvement in soil fertility (ploughing, sowing and weeding). Animal traction depends on the cash crop, off-farm income, household size, age of the head of household, access to road infrastructure, and land quality.

Duy [21] investigated the effects of credit on production levels and production efficiency, using stochastic frontier analysis and quantile regression on a sample of 300 producers. The results confirm the positive influence of credit on production levels and production efficiency. The effects of formal and informal credit seem to be significant, but formal credit has a more beneficial effect than informal credit. Similar results are obtained with Diamouténé [15] using the Endogenous Switching Regression (ESR) estimation method on a sample of 403 producers in the Office du Niger zone in Mali. The author explains the difference by the fact that public formal credit policies are more accessible to farmers, but also that due to its monitoring, it is less diverted from the production circuit.

Dong et al. [22] use an endogenous switching regression model that accounts for both heterogeneity and sample selection issues to examine the effects of credit constraints on agricultural productivity and income of rural households in China on a sample of 2,794 rural households. They identify two groups of individuals: those who are credit constrained and those who are not. The results reveal that, under credit constraints, farmers’ production factors and potentials are limited. Indeed, the study showed that the level of education positively affects the productivity of unconstrained farmers, but does not affect that of credit-constrained farmers. In addition, the lifting of credit constraints would improve agricultural productivity and income of rural households.

In contrast to the work of Dong et al. [22], revealing the adverse effect of the formal credit constraint on production decisions, this result was rejected by Kochar [23]. The author shows that the formal credit constraint does not explain the levels of input use by farm households. Many farms do not need formal sources of finance for their activities. He concludes that the small amounts needed to finance agricultural activities can be available at relatively low cost from the informal sector. The author shows that lack of access to formal credit does not constrain the production decisions of farm households as long as they are able to substitute formal credit with other forms of credit from various rural markets. In Pakistan, Hussain [17] analyses the impact of key agricultural inputs (credit disbursement, area cultivated, fertiliser consumption and water availability) on total output using a time series from 1988 to 2010. The study uses a log-linear Cobb-Douglas production to estimate the impact and importance of these inputs. However, it does not find a significant relationship between total output and credit. This result alerted to the inefficiency of credit disbursements and fertiliser consumption, which merit further study.

3. METHODOLOGY

3.1 Sampling

In Mali, the cotton zone remains very large, with each locality having its own reality. Our survey took into account the CMDT zone of Koutiala for its seniority (first CMDT zone) and the CMDT zone of Fana for reasons of accessibility as it is close to the capital (Bamako) in order to be able to reach more credit institutions. We used the typology still in force within CMDT, which is divided into 5 categories: Type A refers to farms that have two units of cultivation with at least one pair of oxen, a plough, a seeder and a cart; type B refers to farms with only one unit of cultivation with a hitch; type C refers to farms with only an incomplete hitch; and type D refers to farms where the only tools are manual.

We retained 3 types (Well-equipped = type A and Motorised type, Equipped = type B and Less equipped = type C+D). This is due to the low representativeness of the motorised type and a trend towards the disappearance of type D [24]. This work uses survey data collected from 400 family farms in the Fana and Koutiala CMDT zone through stratified sampling at several stages (the zones and farm types forming the strata).

3.2 Analysis Methodology: The Linear Instrumental Variable Model

3.2.1 Model specification: profit function maximisation

This model is built on the standard assumption that the producer makes choices about inputs
and credit use to maximise profit (net income) from cotton production (Fall, 2006):

\[ \pi(P, T, B_m, S, X) = \max_{X > 0} (PQ - T \cdot X) \quad (1) \]

Under duress:

\[ Q = A \times f(X) \quad (2) \]

\[ T \cdot X = B + S \quad (3) \]

\[ X_0 \leq L_m \quad (4) \]

\[ B \leq B_m \quad (5) \]

For equation (1): Q is the total quantity of cotton produced, P is the selling price of cotton, \( X = (X_0, X_1, ..., X_K) \) is the vector of quantities of K+1 basic inputs (land, seed, fertiliser, etc.) used with \( X_0 \) the area sown and \( L_m \) the total area available; \( T \) is the vector of unit prices of the basic inputs; \( f \) is the production frontier function (which gives the maximum possible output for the level of inputs \( X \)); \( A \) is the producer’s technical efficiency index between 0 and 1; \( B \) is the amount of credit obtained and \( B_m \) the maximum amount of credit that the producer can obtain; \( S \) is the savings used for the purchase of inputs (self-financing). Equation (2) describes the technological constraint (expressed in the conceptual framework of frontier production). Equation (3) is the liquidity constraint reflecting the fact that the total expenditure on inputs is exactly equal to the total sum of available financial resources. Equation (4) is the available land constraint for a given season. Equation (5) is the constraint on the amount of credit available.

To analyse the data for this study, drawing on the work of Djato et al. (1996, 1997) and Djato (2001), we used a standardised profit function as follows:

\[ \pi^*(P, z) = F[X_0(P, z), ..., X_K(P, z)] - \sum q_j X^*_j(P, z) \quad (6) \]

\( q_j \) represents the price of factors normalised by the price of the product (cotton); \( F \) is a production function appropriate to the context; \( X^* = (X_0^*, X_1^*, ..., X_K^*) \) is a vector of variables representing the factors of production normalised by the price of cotton and \( z \) is a vector of fixed factors used in the production process.

From this equation, and using the Hotelling- Shephard lemma, we obtain the corresponding factor demand and product supply equations.

\[ \frac{\partial \pi^*(q, z)}{\partial q_j} = -X^*_j \quad \text{avec} \quad j = 1, ..., m \quad (7) \]

Multiplying the two members of the above m equations by \( \frac{\partial q_j}{\partial q} \) we obtain m factor distribution equations as follows (with \( m = K + 1 \)):

\[ \frac{\partial \pi^*(q, z)}{\partial q_j} \cdot \frac{\partial q_j}{\partial q} = -X^*_j \cdot \frac{\partial q_j}{\partial q} = a_j \quad \text{avec} \quad j = 1, ..., m \quad (8) \]

Equations (6) and (8) provide a basis for specifying an empirical model. Following Lau and Yotopoulos (1971), the specification of the system of equations for the standard profit function and factor allocation functions is given by:

\[ \ln \pi^* = \ln A^* + \delta c \text{Access2019} + a_1 \text{Ln}v^* + a_2 \text{Ln}f^* + a_3 \text{Ln}X^* + b_1 \text{Ln}k^* + b_2 \text{Ln}V^* + u_0 \quad (9) \]

\[ \text{ACCESS2019} = \gamma_1 \text{age cm} + \gamma_2 \text{age cm carre} + \gamma_3 \text{situation matri} + \gamma_4 \text{revenu_menage2} + \gamma_5 \text{existence_garantie_nouveau} + \gamma_6 \text{scolaris2} + \gamma_7 \text{type_exploitation2} + \gamma_8 \text{tauxinteret_applique_lc} + \gamma_9 \text{Formation_microprojet_coton} + \varepsilon \quad (10) \]

In this system of equations, \( \pi^* \) represents the normalised profit in CFA francs in relation to the price of cotton. This profit is defined as the revenue (the prices of cotton and other crops multiplied by the quantities sold of cotton and other crops respectively) from which the cost of variable factors is deducted, namely labour, inputs (seeds, organic fertilisers, mineral fertilisers, pesticides) and the livestock used on the farm.

\( A^* \) is the constant at the origin; \( w^* \) is the wage rate normalised by the price of cotton of permanent employees, day labourers and groups of workers; \( f^* \) is the average price of inputs used normalised by the price of the product obtained (cotton); \( X^* \) is the quantity of inputs used; \( K \) is capital and is the sum of all other production costs (depreciation of equipment); \( V \) is the cultivated area in hectares; ACCES2019 is a dummy variable taking the value 1 for farmers with access to credit and the value 0 for those without access to credit.

Such a system of equations used to analyse agricultural production in Mali fulfills properties such as additivity, and having 0 as the mean and a constant variance [25]. In addition, the estimation of this system makes it possible to obtain efficient, unbiased estimators [26].
3.2.2 Choice of explanatory variables

According to the literature, and in a logic of profit maximization, the explanatory variables to be retained to explain the global agricultural income are 15 variables:

- **Access to credit**: ACCES2019 or accesscred: this is the variable estimated with the logit model of determinants of access to equipment credit in Mali [27].
- **Total area sown**: logtotal_area_sown_2018
- **Cost of permanent labour wages**: cost_totalpermanent_employees
- **Cost of daily labour wages**: cost_totallabour_days
- **Cost of wages by group of workers**: cost_workers_group
- **Cotton input costs**: cout_intrants_coton
- **Cost of organic manures**: cout_intrant_furmure_organ
- **Materials on the holding**: logcoutmaterial: the life of the material is reconsidered at its average value for each material asset. The depreciation of equipment used on the holding will therefore be the purchase cost of the equipment divided by its average life.
- **Livestock**: livestock: the existence of livestock is recoded in binary (1=yes or 0=no).
- **Other herds**: otherherd: this variable is also binary recoded (1=yes or 0=no).
- **Quantity sold COTTON in 2019**: logqte_vendo_cotton_2019_hivering
- **Quantity sold 2019 other crops**: logquantvendueautrecultur
- **Sales prices 2019 other crops**: logprixmoyenautreculture
- **Number of active household members**: Number_of_active_household_members: the variable Number of active household members has been added to take account of family labour.
- **Other operating expenses**: Other expenses are all other expenses in the operating account not recorded elsewhere.

The choice of certain variables was made according to the availability of data and the estimation method of the econometric model (by instrumental variables of the agricultural credit).

As for farm income, the variable of interest in the model, it will be taken into account the income from cotton and the income from other crops. For its calculation, it was assumed that the costs of agricultural production were deducted from the income of cotton (according to our data collection method), the other crops increased the agricultural income by the average amount of sales (average price × Average quantity). Thus farm income corresponds to the producer’s profit in our work.

3.2.3 Choice of instrumental variables

With the endogenous variable "Access to credit", we look in the literature at its most significant determinants or explanatory factors that are independent of the dependent variable "agricultural income". These factors are called instrumental variables and make it possible to exogenise the "Access to credit" variable. The variables most commonly used as instruments of access to credit are, according to the literature: the financial environment, the terms and conditions of the loan imposed by the credit institutions, and the social and economic characteristics of the borrowers.

Following this principle, and taking into account the work of Touré and Diop [27] on the determinants of access to equipment credit in Mali, the following instrumental variables of agricultural credit were retained in the model: interest rate, marital status, age as well as age squared, training in microprojects, schooling, the existence of material guarantees, the level of household income and the type of farm.

In this approach, one could have considered the variable "amount of credit received" by the producer instead of the variable "access to credit". And by the same process of choice of instruments, we would obtain the expected results.

3.2.4 Parameter estimation methods

- **Instrumental variable estimation**

Let be the linear model of farm income:

\[ Y = Xa + u \]

With

\[ E(u) = 0, E(u'X) = \sigma^2 I_d, \quad r(X) = K et E(X'X) \neq 0 \]

The last assumption means the non-exogeneity of the explanatory variables X and is a sufficient
reason for using the instrumental variables estimation method. Instead of regressing $Y$ on $X$, in this estimation method, we will regress $Y$ on $\tilde{X}$ which is the projection of $X$ into the vector space generated by the vector of instruments $Z$.

In practice, only some variables of $X$ are exogenous and can be included in the vector of instruments $Z$. We then have:

$$X = [X_1 \, X_2] \quad \text{et} \quad Z = [X_1 \, Z_1]$$

With $X_1$ exogenous variables, $X_2$ endogenous variables and $Z_1$ the instruments of $X_2$.

It is still possible to have a single endogenous explanatory variable, as is the case in our context (access to credit is by hypothesis endogenous to the model).

The instrumental variables estimator is given by:

$$\tilde{a}_{IV} = \left[ X'Z(Z'Z)^{-1}ZX \right]^{-1} \left[ X'Z(Z'Z)^{-1}ZY \right]$$

For comparison, the ordinary least squares estimator is:

$$\tilde{a}_{OLS} = \left[ X'X \right]^{-1} \left[ X'Y \right]$$

When all explanatory variables are exogenous then $\tilde{a}_{OLS}$ gives convergent and asymptotically more accurate estimates than $\tilde{a}_{IV}$. Of course, in the case of endogeneity, the ordinary least squares estimator is biased and one should turn to the instrumental variables estimator. This is why exogeneity tests will be carried out (Hausman test and Lagrange multiplier test) before retaining the final model to be interpreted, the null hypothesis being the exogeneity of the explanatory variables. In addition, validation tests of the instruments will make it possible to retain the optimal $Z$ vector in the event of endogeneity.

- **Estimation by the Heckman method**

By implementing Heckman’s (1976) estimation method, taking into account the possible endogeneity of access to credit, we obtain the first results of the model. Indeed, zero agricultural income should be taken into account as it represents 16% of the population. These are non-profitable situations on the farm. This creates a selection bias in the surveyed sample (see General Introduction). Using this Heckman estimation method, a probit model with a binary dependent variable (the fact that the income is zero or not) will be estimated in a first step. The inverse of the Mills ratio, which measures the selection bias, is then estimated. Finally, $Y$ is regressed for strictly positive values of income, incorporating the inverse of the Mills ratio as an additional explanatory variable in the model. Hence, using the two-step Heckman method, the final model is obtained.

More clearly, the theoretical model of farm income is as follows:

$$Y_i = b'X_i + \varepsilon_i$$

Where:

$Y$ is the dependent variable of agricultural income, $X$ is the vector of explanatory variables, ignoring the problems of endogeneity of access to credit already highlighted above, and $\varepsilon$ is the error term of mean zero and standard deviation $\sigma$.

However, the empirical model to be estimated is

$$Y_i^* = b'X_i + \varepsilon_i$$

$Y_i^*$ is only observable if individual $i$ meets certain criteria. In our case, the producer's farm income should be strictly positive. $Y^*$ is called the latent variable of the Heckman model.

We define a variable $M^*$ whose variations can be explained by other variables than those explaining the variations of $Y^*$.

$$M_i^* = \gamma'W_i + u_i$$

$Y^*$ is only observed if $M^*$ takes certain values. Here, $M^*$ must be strictly positive.

The values of $Y$ are therefore observed with a selection bias. We have:

$$Y_i = Y_i^* \text{ si } M_i^* > 0$$

$$Y_i = 0 \text{ si } M_i^* \leq 0$$

But, since only the sign of $M^*$ is observed, we define a binary variable $M$ such that:

$$M_i = 1 \text{ si } M_i^* > 0$$

$$M_i = 0 \text{ si } M_i^* \leq 0$$

$M^*$ is here the producer's profit and $M$ becomes the binary variable of income ($1$ for those with a strictly positive income and $0$ otherwise).
It is assumed that the pair \((u_i, \varepsilon_i)\) has a normal joint density of mean \((0; 0)\), variance \(\sigma_u^2\) and \(\sigma_\varepsilon^2\) whose correlation is \(\rho\). Using the traditional results concerning the moments of a truncated normal joint density (Greene, 1993), we can write:

\[
E(Y| M_i = 1) = b'X_i + \rho \sigma_Y \lambda_i
\]

With \(\lambda_i = \lambda(Y W_i)\) the inverse of the Mills ratio.

The following model should then be estimated:

\[
Y_i = b'X_i + \rho \sigma_Y \lambda_i + \nu_i
\]

In which \(Y_i\) is only observed when \(M_i = 1\).

The estimation of the linear model is done, now with two dependent variables \(M\) and \(Y\), in two steps:

- **First step**: the probit model (selection equation) is estimated by maximum likelihood with dependent variable \(M\) and explanatory variables \(W\) and \(X\), in order to obtain an estimate of the parameters \(\gamma\) and an estimate of the inverse of the Mills ratio \(\lambda_i\) by:

\[
\lambda_i = \frac{f(\gamma W_i)}{1 - F(\gamma W_i)}
\]

Where:

- \(f(.)\) and \(F(.)\) are the density and distribution function, respectively, of the centred reduced normal distribution.

- **Second step**: we estimate the coefficients \(b\) and \(b_0 = \rho \sigma_Y\) by ordinary or generalized least squares, regressing \(Y\) on \(X\) and \(\lambda_i\) on the positive values of the dependent variable only.

The standard deviations of the coefficients, which are underestimated with this method, must be corrected (Heckman, 1979). However, the coefficient estimates remain unbiased in all cases.

For the choice of the right model, the classical hypotheses on the residuals of logistic regression (autocorrelation, heteroscedasticity, multicollinearity, endogeneity of the explanatory variables...) are tested and corrections are made when they are violated. Instrument validation tests are also carried out, as well as the LR test for the existence of selection bias in the sample, which would be due to the zero income of certain producers (see Appendix).

4. PRESENTATION AND ANALYSIS OF RESULTS

4.1 Level of Equipment and Agricultural Productivity

We find that large farms have an average of 2 complete hitches (seven (7) ploughing oxen, two (2) ploughs, etc.). This situation could be explained by the fact that in Fana and Koutiala producers were lucky enough to benefit from favourable equipment conditions at a time when the sector was doing well.

In this research, we define cotton income or cotton profit as the difference between operating revenues and production costs.

In the last fourteen years, i.e. from 2005-2019, the profit from seed cotton has been strongly affected by the price of seed cotton and the price of inputs, combined with lower yields. In other words, the producer price peaked in the 2011-2012, 2012-2013 and 2018-2019 seasons. These times coincide with the period when Mali regained its position as the leading producer in West Africa. This explains a strong positive correlation between the quantity produced and the price of seed cotton.

In Table 2, we see that the well-equipped farmers are the only ones to have a positive profit with the cost of family labour and the cost of organic manure, i.e. 340,252 FCFA. The less equipped producers have the lowest profit with the valuation of the cost of family labour and the cost of organic manure (-194,197 FCFA). For producers with equipment, the profit with valuation of the cost of family labour and the cost of family organic manure is also negative (-106,241 FCFA). In total, on average, the farms have a negative profit (-194,197 FCFA) when the cost of family labour and the cost of organic manure are taken into account.

The analysis of the ANOVA test of average profits by farm type shows that there is a significant difference between cotton income, with the cost of family labour and the cost of organic fertiliser taken into account (strong difference between the well-equipped type and the other types of farm). We note that the standard deviations are extremely high in terms of profits for all types of producers. This is due to a large difference between the minimum and maximum values.
### Table 1. Level of equipment by type of farm

<table>
<thead>
<tr>
<th>Equipment in warranty</th>
<th>Well-equipped</th>
<th></th>
<th>Equipped</th>
<th></th>
<th>Less Equipped</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Standard deviation</td>
<td>Average</td>
<td>Standard deviation</td>
<td>Average</td>
<td>Standard deviation</td>
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<td>0</td>
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<td>1</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>Number of ploughs</td>
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<td>2</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
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<td>1</td>
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<td>1</td>
<td>1</td>
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<td>Number of draught oxen</td>
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<td>1</td>
</tr>
<tr>
<td>Number of Cattle</td>
<td>12</td>
<td>16</td>
<td>4</td>
<td>7</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Number of goats</td>
<td>15</td>
<td>49</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Number of Sheep</td>
<td>12</td>
<td>18</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Number of permanent buildings</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Area Planted (ha)</td>
<td>27</td>
<td>69</td>
<td>11</td>
<td>27</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Area of cultivable land (ha)</td>
<td>24</td>
<td>18</td>
<td>11</td>
<td>8</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Number of vehicles</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of motorbikes</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Authors based on Survey 2019 data

### Table 2. Operating account by type of producer in 2018-2019 in FCFA

<table>
<thead>
<tr>
<th>Available at</th>
<th>Well equipped</th>
<th></th>
<th>Equipped</th>
<th></th>
<th>Less Equipped</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Standard deviation</td>
<td>Average</td>
<td>Standard deviation</td>
<td>Average</td>
<td>Standard deviation</td>
<td>Average</td>
</tr>
<tr>
<td>Production kg</td>
<td>5712</td>
<td>4211</td>
<td>1999</td>
<td>1661</td>
<td>1341</td>
<td>1002</td>
<td>3745</td>
</tr>
<tr>
<td>Price of seed cotton (FCfa/kg)</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>Production values</td>
<td>1 488 964</td>
<td>1 254 875</td>
<td>509 711</td>
<td>423 511</td>
<td>342 017</td>
<td>280 733</td>
<td>955 100</td>
</tr>
<tr>
<td>Depreciation (FCFA)</td>
<td>65 635</td>
<td>143 160</td>
<td>43 390</td>
<td>85 141</td>
<td>20 929</td>
<td>19 974</td>
<td>52 921</td>
</tr>
<tr>
<td>Input costs (CMDT credit) in FCFA</td>
<td>483 140</td>
<td>447 500</td>
<td>221 408</td>
<td>401 281</td>
<td>186 091</td>
<td>141 795</td>
<td>345 478</td>
</tr>
<tr>
<td>Permanent work factors in the operation</td>
<td>156 346</td>
<td>124 176</td>
<td>168 077</td>
<td>218 113</td>
<td>160 256</td>
<td>158 742</td>
<td>320 512</td>
</tr>
<tr>
<td>Labour inputs Daily wage earners (FCFA)</td>
<td>10 513</td>
<td>10 671</td>
<td>17 778</td>
<td>20 903</td>
<td>14 679</td>
<td>12 453</td>
<td>14 023</td>
</tr>
<tr>
<td>Group of workers (FCFA)</td>
<td>43 720</td>
<td>48 525</td>
<td>24 560</td>
<td>21 069</td>
<td>27 598</td>
<td>19 471</td>
<td>34 410</td>
</tr>
<tr>
<td>Family labour (MOF (FCFA))</td>
<td>389 227</td>
<td>261 238</td>
<td>226 647</td>
<td>161 793</td>
<td>222 727</td>
<td>168 213</td>
<td>305 175</td>
</tr>
<tr>
<td>Cost of Organic Manure Input in FCFA (CIFO)</td>
<td>104 450</td>
<td>72 680</td>
<td>64 296</td>
<td>66 538</td>
<td>74 944</td>
<td>65 049</td>
<td>93 316</td>
</tr>
<tr>
<td>Production costs without MOF (FCFA) and without CIFO</td>
<td>540 205</td>
<td>515 849</td>
<td>280 600</td>
<td>416 238</td>
<td>211 814</td>
<td>150 192</td>
<td>304 928</td>
</tr>
<tr>
<td>Production costs with MOF (FCFA) and with CIFO</td>
<td>1 047 177</td>
<td>688 952</td>
<td>571 459</td>
<td>488 091</td>
<td>509 285</td>
<td>312 052</td>
<td>794 872</td>
</tr>
<tr>
<td>Gross margin without MOF (FCFA) and without CIFO</td>
<td>901 953</td>
<td>923 282</td>
<td>251 702</td>
<td>490 200</td>
<td>130 403</td>
<td>192 739</td>
<td>553 058</td>
</tr>
<tr>
<td>Gross margin with MOF (FCFA) and with CIFO</td>
<td>405 877</td>
<td>884 590</td>
<td>-67 660</td>
<td>488 943</td>
<td>-167 268</td>
<td>240 619</td>
<td>153 701</td>
</tr>
<tr>
<td>Net margin without MOF (FCFA) and without CIFO</td>
<td>835 681</td>
<td>916 083</td>
<td>208 167</td>
<td>484 624</td>
<td>103 474</td>
<td>180 522</td>
<td>500 504</td>
</tr>
<tr>
<td>Net margin with MOF (FCFA) and with CIFO</td>
<td>340 252</td>
<td>865 395</td>
<td>-106 241</td>
<td>490 111</td>
<td>-194 197</td>
<td>238 943</td>
<td>-194 197</td>
</tr>
<tr>
<td>Net margin without TF without CIFO per ha</td>
<td>113 852</td>
<td>95 107</td>
<td>76 726</td>
<td>141 192</td>
<td>40 931</td>
<td>73 862</td>
<td>91 584</td>
</tr>
<tr>
<td>Net margin with TF with CIFO per ha</td>
<td>12 210</td>
<td>136 148</td>
<td>-55 914</td>
<td>166 160</td>
<td>-84 259</td>
<td>98 913</td>
<td>-25 414</td>
</tr>
</tbody>
</table>

Source: Authors based on Survey 2019 data
4.2 Presentation of Estimation Results

All continuous variables in the model are log-transformed in order to interpret the estimated coefficients in terms of elasticity. After performing the estimation procedures by the Heckman method with VI, we have the final results in Tables 3 and 4. The coefficients of the model are positive and significant at the 5% level, which suggests that the producers are in a profit maximisation logic to the detriment of cost minimisation at all costs (as is the case in capital-intensive sectors).

At equilibrium on the agricultural market, only the variable Quantity sold of cotton is significant in the selection equation. It is only, in spite of everything, the variation in the quantity sold of cotton that is in general the determinant of zero farm income. We reason in a simultaneous situation of realized agricultural production, of profits obtained by some producers, of agricultural credits granted to some producers.

The coefficient associated with the inverse of the Mills lambda ratio is equal to 0.4084 which is less than 1. The value of rho is 44%. There is then a negligible relationship between having a profit or not, after repayment of the loans, are: the cost of material goods and, of course, the quantity of cotton sold. The latter, as well as access to equipment credit, have a positive effect on whether or not producers make a profit from farming, unlike the prices of other crops and the costs of material goods, which have a negative effect.

The probit model of zero income is also estimated

The two variables that are significant at the 10% threshold in the fact of having a profit or not, after repayment of the loans, are: the cost of material goods and, of course, the quantity of cotton sold. The latter, as well as access to equipment credit, have a positive effect on whether or not producers make a profit from farming, unlike the prices of other crops and the costs of material goods, which have a negative effect.

Table 3. Heckman regression with credit instrumental variables

| Main equation | Coef.  | Std. Err. | z     | P>|z|  | 95% Conf. Interval |
|---------------|--------|-----------|-------|------|-------------------|
| accesspredit  | 0.3494** | 0.1434   | 2.44  | 0.015 | 0.0683-0.6305     |
| log_sale_cotton_2019_wintering | 0.2986*** | 0.0481 | 6.21  | 0.000 | 0.2044-0.3928     |
| logquantvenduuatrecultur | 0.1575*** | 0.0217 | 7.26  | 0.000 | 0.115-2.0      |
| logprixmediumautreculture | 1.0826*** | 0.0803 | 13.48 | 0.000 | 0.9253-1.24     |
| logcoutmaterial | 0.2396*** | 0.0494 | 4.85  | 0.000 | 0.1427-0.3365   |
| total_area_of_fill_2018_log | 0.479*** | 0.0943 | 5.08  | 0.000 | 0.2942-0.6638   |

| Selection equation | Coef. | Std. Err. | z     | P>|z|  | 95% Conf. Interval |
|--------------------|-------|-----------|-------|------|-------------------|
| accesspredit       | 0.2474 | 0.4568 | 0.54  | 0.588 | -0.6479-1.1427   |
| log_sale_cotton_2019_wintering | 0.2979*** | 0.1113 | 2.68  | 0.007 | 0.0797-0.5161   |
| logquantvenduuatrecultur | 10.079 |         |       |      |                   |
| logprixmediumautreculture | -0.2333 | 0.2769 | -0.84 | 0.399 | -0.776-0.3094    |
| logcoutmaterial     | -0.1369 | 0.1601 | -0.85 | 0.393 | -0.4507-0.1769   |
| total_area_of_fill_2018_log | 0.1198 | 0.2192 | 0.55  | 0.585 | -0.3098-0.5494   |
| /athrho             | 0.4712*** | 0.1453 | 3.24  | 0.001 | 0.1864-0.7561    |
| /lnsigma            | -0.0726* | 0.0392 | -1.85 | 0.064 | -0.1494-0.0042   |
| rho                 | 0.4392 | 0.1173 |       | 0.1842 | 0.6388          |
| sigma               | 0.93  | 0.0364 |       | 0.8612 | 1.0042          |
| lambda              | 0.4084 | 0.1132 |       | 0.1866 | 0.6303          |

** LR test of indep. eqns. (rho= 0): chi2(1) = 10.19 Prob>chi2 = 0.0014

Source: Authors based on 2019 survey data

*** significant at the 1% level (P<.01); ** significant at the 5% level (P<.05); *
** significant at the 10% level (P<.1)
4.3 Interpretation of Estimation Results

The medium to long-term credit allows for the use of more capital goods on the farm. This use of equipment increases farm productivity, and in turn farm income. His results are a confirmation of the work of Diamouténé [15], Feder et al. [14] and Duy [28] finding a positive effect of agricultural credit on agricultural productivity. Other authors have justified this positive effect through increased agricultural yields (Mahoukedé, 2015); [13]. We are not in a situation where agricultural credit equals more unmanageable operating expenses as Sy [2] claims. The amounts of credit received by producers are significantly the same from one type of farm to another (see section 4.1). This suggests that the amounts of credit received are still too low, even in the case of a well-equipped farm. Cotton farmers have ample opportunity to increase their production and farm income, regardless of the level of agricultural credit currently received. All that is needed is to grant them more equipment credit.

Indeed, the mere fact of using capital goods is, as a reminder, synonymous with an increase in farm income (with an elasticity of 24%). The use of capital goods is a form of investment in agricultural production systems, giving rise to increased profits [29]. Undoubtedly, agricultural production differs significantly from one type of farm to another (see subsection 4.1). The increase in farm output due to the increase in capital goods used is equivalent to the increase in farm income automatically, despite the level of capital goods costs. Although significant, the effect of capital costs on having a farm income surplus is weakly negative. Each producer is required, however, to control his level of capital goods costs to avoid reducing his chances of having a non-zero farm income (coefficient of -0.21 for a p-value of 0.09).

The increase in the quantities sold (cotton and other crops) is equivalent to saying that agricultural production is increasing because there is no system for storing the production of the previous crop year. As production is increasing, agricultural producers benefit. The increase in production means the use of more capital goods. There is a positive relationship between cotton production and farm type. And as explained above, capital goods contribute to productivity gains and thus to the surplus of farm income for producers. The other crops have a relatively lesser effect on farm income as they are practically food crops. Cotton is the main cash crop for these farmers. Thus, the increase in the quantities sold of the other crops is rather related to the increase in the quantities sold of cotton [20]. The price elasticity of other crops in relation to farm income is very high (over 100%). When farmers decide to increase their production of other crops as a result of higher prices for other crops, the quantities produced of cotton also increase, and farm income follows.

It is clear that if cotton farmers produce more, they will have more income despite their difficulties in accessing credit and the management problems already reported (see subsection 5.1). The same observation was already made in the use of capital goods on the farm. The increase in capital goods used increases agricultural production. In addition, there is a clear difference in the area sown between producers by type of farm (well-equipped producers and others). This could justify the fact that the increase in the area sown only increases farm income. In fact, capital goods should increase if more land is to be sown. Certainly, if producers want to increase the

---

**Table 4. Estimation of the zero income probit model**

<table>
<thead>
<tr>
<th>Probit regression</th>
<th>Number of obs=393</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log likelihood=-70.423173</td>
<td>Coef.</td>
</tr>
<tr>
<td>accesspreadit</td>
<td>0.5701</td>
</tr>
<tr>
<td>log_sale_cotton_2019_wintering</td>
<td>0.268**</td>
</tr>
<tr>
<td>logquantvendautreculture</td>
<td>2.2556</td>
</tr>
<tr>
<td>logprixmediumautreculture</td>
<td>-0.0638</td>
</tr>
<tr>
<td>logcoutmaterial</td>
<td>-0.2069*</td>
</tr>
<tr>
<td>total_area_of_fill_2018_log</td>
<td>0.1847</td>
</tr>
</tbody>
</table>

Source: Authors based on 2019 survey data

*** significant at the 1% level (P<.01); ** significant at the 5% level (P<.05); 
* significant at the 10% level (P<.1)
area sown, they must have the necessary financing in the farm.

5. CONCLUSION

The general objective of this study is to analyse the effect of equipment credit on the income of cotton producers in the CMDT zones of Koutiala and Fana in Mali.

A logistic regression was used to analyse the determinants of zero profit for some producers and a Heckman multiple linear regression by credit instrumental variables was used to analyse the effect of credit on farm income.

Concerning the estimation of the logistic regression model by the maximum likelihood method, the significant variable affecting the existence of non-profits for cotton producers at the 5% threshold is the quantity sold of cotton, the other significant variables at the 10% threshold are access to equipment credit and the cost of material goods on the farm.

As for the estimation of the second multiple regression model by instrumental variables, by implementing the estimation method of Heckman (1979) to take into account the zero profit for 16% of the producers, the results show that the variables that lead to an increase in income at the 5% threshold following their increase are: access to credit, quantity of cotton sold, costs of material goods used on the farm, total area sown, quantity sold of other crops, selling price of other crops.

Based on these results, we can make some policy recommendations.

5.1 Boosting Cotton Production

Since the price of cotton is fixed in advance, one way to increase producers' income is to increase agricultural production, i.e. the quantity of cotton produced. This can be done by increasing agricultural productivity with the use of more material goods, increasing agricultural yields with the use of more agricultural inputs and increasing the area sown. This strong increase in production must be accompanied by the possibility of selling the agricultural supply on the national market (processing of cotton in factories) and internationally (exports), in order to avoid inflationary pressures (the price of cotton should fall if this continues), a drop in income or a loss of profit for producers.

5.2 Making Other Crops More Beneficial to Producers

At the same time as promoting cotton production, the prices of other crops should be increased because the price elasticity of these crops is very high (over 100%). As the production of other crops goes hand in hand with that of cotton, as soon as the prices of other crops increase, farm income will automatically increase.

5.3 Granting More Equipment Credit

Access to credit is the driving force behind the increase in agricultural production in the sense that it allows producers to have capital goods on the farm. These capital goods guarantee an increase in agricultural productivity, agricultural yields, and ultimately agricultural income. Agricultural credit could also play a role against poverty among cotton producers insofar as it helps to avoid having zero agricultural income, and thus to increase production in general (quantity of cotton and other crops sold). All cotton producers, in their majority, would have a surplus income (after payment of the loan) if they had access to equipment credit.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

5. Koné Y. Le marché du crédit face aux risques agricoles : la riziculture de l'Office


28. Duy VQ. The role of access to credit in rice production efficiency of rural households in the Mekong Delta, Vietnam. Centre for ASEAN Studies and Centre for
APPENDIX:

Tests and estimates of the Credit Impact on Producer Income model

1. Choosing the right model (reducing the number of explanatory variables)

The first step in choosing the right model is to reduce the number of explanatory variables. A multicollinearity between several explanatory variables, not necessarily two by two, was observed. This is why the method of successive elimination of explanatory variables was adopted. In this, Klein and Farrar-Glauber tests of multi-collinearity were performed (Chi2 statistic (91) = 1052.876).

With the information criteria of AIC and BIC, and the log likelihood, we finally retained 6 explanatory variables which are: Access to credit, Quantity sold of cotton, Quantity sold of other crops, Average selling price of other crops, Equipment on the farm and Total area sown.

<table>
<thead>
<tr>
<th></th>
<th>logcrve-1 access-c cou-st exc-c cou-s-1 cout-j-m cout-i-e logQTE-0 logqua-e logpri-e e chefel mchorce-1 logcou-1 log-2010 B-hati-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>logcrve-1</td>
<td>1.0000</td>
</tr>
<tr>
<td>accesscredit</td>
<td>0.0377  1.0000</td>
</tr>
<tr>
<td>cout_total-qs</td>
<td>0.0384  0.0531  1.0000</td>
</tr>
<tr>
<td>cout_saler-1</td>
<td>0.0169  0.0530  0.1207  1.0000</td>
</tr>
<tr>
<td>cout_inter-1</td>
<td>0.0385  0.0383  0.1720  0.0075  0.2063  1.0000</td>
</tr>
<tr>
<td>Cout_inter-e</td>
<td>0.0192  0.0342  0.0656  0.0102  0.0655  0.3937  1.0000</td>
</tr>
<tr>
<td>logQTE-0</td>
<td>0.5378  0.5311  0.0129  0.0701  0.2004  0.4749  0.2875  1.0000</td>
</tr>
<tr>
<td>logqua-1</td>
<td>0.0418  0.0094  0.0239  0.0736  0.0416  0.1034  0.0176  0.7616  1.0000</td>
</tr>
<tr>
<td>logpri-e</td>
<td>0.0227  0.0109  0.0125  0.0851  0.0059  0.0410  0.0109  0.0176  0.0709  1.0000</td>
</tr>
<tr>
<td>chefel</td>
<td>0.0108  0.0319  0.0242  0.0443  0.0100  0.1664  0.2712  0.0579  0.0024  1.0000</td>
</tr>
<tr>
<td>mchorce-1</td>
<td>0.1196  0.0288  0.0340  0.0365  0.1066  0.1491  0.1571  0.0897  0.1076  0.2164  1.0000</td>
</tr>
<tr>
<td>logcou-1</td>
<td>0.0023  0.0376  0.0356  0.0011  0.1997  0.2780  0.0797  0.0464  0.3294  1.0000</td>
</tr>
<tr>
<td>log-2010</td>
<td>0.2592  0.0042  0.1243  0.0059  0.3595  0.5366  0.3254  0.5683  0.2503  0.0204  0.1830  0.2013  0.3901  1.0000</td>
</tr>
<tr>
<td>Bhni-j_2015</td>
<td>0.5666  0.1073  0.0001  0.0380  0.2197  0.3714  0.2785  0.0003  0.0230  0.0320  0.2015  0.5990  1.0000</td>
</tr>
</tbody>
</table>

Chart 1. Correlation matrix

2. Validation of the model through testing and validation of instruments

Hypothesis testing of residuals:

To validate the model, the Ramsey\(^1\) and normality tests\(^2\) concluded that the model was misspecified, but the residuals were confirmed to be normal.

Heteroscedasticity tests are performed comparatively. The results of the tests are reported in Tables 5 and 6. Each of the tests gives p-values of less than 5%. It is concluded that there is heteroscedasticity in the errors.

In the following, the generalized linear model is chosen for the estimations, while retaining only the 6 explanatory variables of the agricultural income which are already significant.

\(^1\) F(3,323)=13.45
\(^2\) P-value=0.0000
Table 5. Breusch-pagan heteroscedasticity tests

```
. hettest
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of logrevenuagricol

chi2(1) = 36.65
Prob > chi2 = 0.0000
```

Source: Authors based on 2019 survey data

Table 6. Cameron and Trivedi Heteroscedasticity Tests

```
. ***on effectue le test d'heteroscedasticité des erreurs
. estat inttest

Cameron & Trivedi’s decomposition of IM-test

<table>
<thead>
<tr>
<th>Source</th>
<th>chi2</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heteroskedasticity</td>
<td>242.64</td>
<td>26</td>
<td>0.0000</td>
</tr>
<tr>
<td>Skewness</td>
<td>136.82</td>
<td>6</td>
<td>0.0000</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.01</td>
<td>1</td>
<td>0.1561</td>
</tr>
<tr>
<td>Total</td>
<td>441.46</td>
<td>33</td>
<td>0.0000</td>
</tr>
</tbody>
</table>
```

Source: Authors based on 2019 survey data

Choice of explanatory variables in the selection equation:

The estimation tables of the econometric model (cf. Section 3 in the Appendix) present the estimation of the Heckman model by instrumental variables of agricultural credit with the 6 explanatory variables in the selection equation.

A second model is then estimated, where the 3 variables Access to credit, Quantity sold of other crops and Price of other crops are removed from the selection equation. Indeed, these variables are not significant at the 5% level in the selection equation.

The Hausman test allows us to see if there is a significant difference between the two models.

According to this test, there is a significant difference between the estimated coefficients of the two models. Thus, the optimal choice of explanatory variables in the selection equation is: Access to equipment credit, Quantity sold of cotton, Quantity sold of other crops, Average selling price of other crops, Cost of material goods on the farm and Total area sown. A second likelihood ratio test (LR test) is performed:
The null hypothesis is rejected according to the two previous tests.

Moreover, for the second model with 3 explanatory variables of zero income, the test of independence between the main equation and the selection equation leads to the rejection of the null hypothesis of non-existence of selection bias (P-value= 0.1044). Therefore, we could estimate this model by the generalized least squares method, then estimate the Probit equation separately. As for the first model with 6 explanatory variables, we accept the null hypothesis of independence between the two equations (P-value= 0.0025). There is therefore a significant selection bias.

In summary, the first model with the 6 explanatory variables in the selection equation with the Heckman method is retained in what follows, as the 16% zero income of producers suggests that selection bias should be taken into account.

**Exogeneity and validation testing of agricultural credit instruments:**

The Hausman test indicates a Chi-square statistic of 31.6. According to this test, there is a significant difference between the estimated coefficients of the two models.

The LR test shows a negative test statistic However, the test statistic should not take negative values. No conclusion can be drawn from the test.

Subsequently, the improved Hausman test is performed. The coefficients of Access to credit in the two models differ significantly (0.27 for the model without IV and 0.43 for the model with IV). The null hypothesis of exogeneity of the explanatory variables is rejected. Therefore, the model estimated by the Heckman method without VI is significantly different from the model estimated by the Heckman method with VI.

As before, for the model without IV, the test of independence between the main equation and the selection equation leads to the acceptance of the null hypothesis of non-existence of selection bias (P-value= 0.1310). As for the second model with IV, we have already accepted the null hypothesis of independence between the two equations (P-value= 0.0025).

Therefore, the model estimated by the Heckman method with VI is retained, as the percentage of 16% of zero income of producers suggests taking into account the selection bias. Thus, the model estimated by the Heckman method with VI of credit will be retained for the following.

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3 Of course, if this theoretical constraint was not imposed, the model with 3 explanatory variables in the selection equation would be chosen.
3. Econometric model estimates

| logrevenuagricol | Coef. | Std. Err. | z   | P>|z| | [95% Conf. Interval] |
|-----------------|-------|-----------|-----|-----|---------------------|
| accesspredit    | .4317546 | .1450402 | 2.90 | 0.004 | .1496412 - .7238681 |
| logQTEVENDEUCOTON2019HIVE-Z | .3164064 | .0516094 | 6.19 | 0.000 | .2152655 - .4175473 |
| logQTEVENDEUCOTON2019HIVE-Z | .124419 | .0135286 | 9.27 | 0.000 | .0961437 - .1625433 |
| logprimaireenculture | 1.098171 | .0807287 | 13.23 | 0.000 | .905946 - 1.223397 |
| logcousinmatieriel | .2346611 | .0513327 | 4.58 | 0.000 | .1342509 - .3354713 |
| logSUPERFICIEIOTALEEMS-2010 | .520668 | .0963007 | 5.47 | 0.000 | .3301227 - .7116143 |

`select` logQTEVENDEUCOTON2019HIVE-Z 0.1697945 .0515675 2.61 0.009 0.0426958 0.3972924 logcousinmatieriel -0.0781838 .0448673 -1.71 0.086 -0.1659405 .0096688 logSUPERFICIEIOTALEEMS-2010 0.2102162 .1303796 1.57 0.115 -0.0534085 .4761233 /athcho .4396308 .2583112 1.70 0.088 -0.0666439 .9459115 /lnsigma -0.0512088 .0513393 -1.00 0.319 -0.1513938 .0495222

cho 0.4323994 .2147791 -.0665514 .7572655 sigmar 0.9600822 .0482279 .8590428 1.000769 lambda .3927054 .2172875 -.0331703 .8165811

LR test of indep. eqns. (cho = 0): chisq(1) = 2.64 Prob > chisq = 0.1044

Chart 3. Heckman 3-variable regression in the selection equation with instrumental variables of agricultural credit

- model LR test inappropriate with noconstant option performing Wald test instead

Iteration 0: log likelihood = -274.48628
Iteration 1: log likelihood = -165.86352
Iteration 2: log likelihood = -161.91942
Iteration 3: log likelihood = -161.77831
Iteration 4: log likelihood = -161.7783

Probit regression

 Number of obs = 396
 Wald chisq(3) = 175.81
 Log likelihood = -161.7783

| select | Coef. | Std. Err. | z   | P>|z| | [95% Conf. Interval] |
|--------|-------|-----------|-----|-----|---------------------|
| logQTEVENDEUCOTON2019HIVE-Z | .1667753 | .0589863 | 2.82 | 0.005 | .0506882 - .2828624 |
| logcousinmatieriel | -.0270514 | .0422829 | -1.58 | 0.073 | -0.1559446 .0018918 |
| logSUPERFICIEIOTALEEMS-2010 | .2913969 | .1356339 | 1.71 | 0.089 | -.0044459 .4972425 |

Chart 4. Probit model of zero income

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Chart 5. Heckman regression without agricultural credit instrumental variables

**Iteration 1:**  log likelihood = -169.64961
**Iteration 2:**  log likelihood = -167.81704
**Iteration 3:**  log likelihood = -167.66611
**Iteration 4:**  log likelihood = -167.66588

**Probit regression**
- Number of obs  =  400
- Wald chi2 (4)  =  172.63
- Log likelihood = -167.66588  Prob > chi2  =  0.0000

| select  | Coef.   | Std. Err. | z       | P>|z|    | [95% Conf. Interval] |
|---------|---------|-----------|---------|--------|---------------------|
| ACCESS2019  | 0.577069 | 0.192836  | 2.93    | 0.003  | 0.035933 to 0.937967 |
| logSTEVENDUECOTON2015HIVERAGE | 0.1636231 | 0.6872122 | 2.70    | 0.007  | 0.046293 to 0.2826109 |
| logcoutublenmatériel | -0.0848204 | 0.0438063 | -1.94   | 0.053  | -0.1706792 to 0.0010384 |
| logSUPERFICIELTOTALSEMELAYE2018 | 0.2415127 | 0.1362653 | 1.77    | 0.076  | -0.0255623 to 0.508578 |

Chart 6. Probit model of zero income

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